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GEOLOGICAL SURVEY OF MISSOURI.

ARTHUR WINSLOW, STATE GEOLOGIST.

VOL. II.

A REPORT

ON THE

IRON ORES OF MISSOURI

FROM

FIELD WORK PROSECUTED DURING THE YEARS

1891 and 1892.

With 62 Illustrations and One Map.

BY

FRANK L. NASON, Assistant Geologist.

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LETTER OF TRANSMITTAL.

OFFICE OF THE GEOLOGICAL SURVEY,
JEFFERSON CITY, MISSOURI,
December 17th, 1892.

To the President, Governor David R. Francis, and the members of the Board of Managers of the Bureau of Geology and Mines:

GENTLEMEN — I have the honor to transmit, herewith, a Report upon the Iron Ores of Missouri, by Mr. Frank L. Nason, assistant geologist.

During the progress of the earlier surveys of the State the iron ores have been subjects of more or less attention. In Part II, of the Report of 1854, the two important iron mines of southeastern Missouri, the Iron mountain and Pilot Knob deposits, were described by Dr. Litton. In Chapters III., IV., V. and VI. of the Report of 1872, or what is known as the Pumpelly Report, the iron ores of the State received fuller treatment than ever before, by Dr. Adolph Schmidt. These chapters covered the iron ores of the porphyry region, the specular ores in sandstone, the red hematites and the deposits of limonite in limestone. In the Report of 1873-74, or the Broadhead Report, the limonites of southeastern Missouri are described.

The fact that these ores had already received a good share of attention in these earlier reports influenced the present Survey to delay their further examination until other subjects, which had received, heretofore, less study and which demanded notice, had been provided for. During the past few years, however, there has been a noticeable and lamentable decline in the iron industry of the State. Reference to Appendix B, at the end of this Report, will show the extent to which the iron ore production of the State has fallen off. Missouri, from having been in the year 1880 the sixth State in the Union in the production of iron ores, has now fallen to the rank of the thirteenth State.

It was largely in recognition of the fact of this decline of Missouri's iron industry that the investigation of the iron deposits of the State was resumed in 1891. It was thought that a careful study of the region in which the various ores occur, [illegible]ided by the light thrown upon the deposits by the development [illegible] years which have elapsed since the last re[illegible] would be reached which

would lead to the discovery of new ore deposits. How far and in what manner these anticipations have been realized will be detailed in the following pages.

Mr. Nason began work for the Survey early in the summer of 1891. His field work was completed and the greater part of his report written by the end of the summer of the year 1892. As is self-evident, such an amount of work could not be accomplished in so short a period without a thorough knowledge of the subject and a mastery of the methods of work, combined with unflagging industry. Mr. Nason exhibited all of these qualities and he is to be complimented and the State to be congratulated upon the product of this short period of work.

In the first part of the report Mr. Nason describes, in successive chapters, the various classes of ores, entering into detail with certain types of each class and discussing quite fully the origin and general geology of the different kinds of deposits. His theoretical deductions concerning the sources of the iron ores and their modes of accumulation are of the most direct value in the future development of the ores. Although they may be termed by some, mere theories, they are theories based upon a careful observation and study of all the available facts. Such study is the only sound basis of knowledge, and the conclusions reached by it are always worthy of respect. It is true that sufficient facts are not always available for an absolute certainty to be reached; at times a conclusion may be considered to rank as high as a certainty; at other times it may deserve to rank merely as a suggestion. In all cases it is the best that can be obtained and in this light is always valuable. Correspondingly the results reached in this report are of variable value. Some conclusions which Mr. Nason has reached he shows are indubitable and can be followed without hesitation; others he offers as mere suggestions, such alone as the meager supply of facts will allow of.

The second part of this Report consists entirely of short descriptions of the more prominent iron ore localities of the State, visited and examined by various members of this and earlier Surveys. In the Schmidt Report of 1872, 257 such localities were mapped. On the map accompanying the present report 636 are located. This additional work was principally done by Mr. E. H. Lonsdale during the spring and summer of this year. He is also the author of many of the descriptions here published. It will be noted, however, that a large number of the descriptions from the report of 1872 are reprinted here. The reason for this is that at some of these localities the opportunities for examination are at present not so good as they were when the earlier work was done; but in most cases the copied descriptions are of local-

ities at which no further work has been done since that time, and, hence, nothing can be added to the earlier writings. The descriptions of these occurrences are sometimes very brief. This is, however, necessarily so in many cases, because very little is to be seen. The principle has been followed out, however, that a few facts are better than none at all and that even a few words, describing the topographic location and the surface occurrences of ore, were better than a mere designation of the locality on the map. These descriptions must be read with an understanding of the general conclusions expressed in the preceding chapters in order that the prospector or miner may use them to the best advantage.

In the township index, at the end of this volume, will be found a complete list of all iron ore localities described, arranged by townships. The idea of this index is to enable one to see at a glance just what deposits occur and are described within any specified area.

It will be noticed that throughout this report the term Cambrian is applied to the rocks of the Ozark region in place of the term Silurian, which has heretofore been used. This, as explained in a foot-note on page 17, is because the stratigraphic studies of the Survey are tending to the conclusion that these rocks belong more properly to the Cambrian age than to the Silurian. The evidence in support of this we hope to adduce soon in a future publication of the Survey. Suffice it here to say that such evidence seems sufficient to warrant the departure here from previously accepted practice.

Not only, however, is it probable that changes will be made in the age assigned the members of the Ozark series, but, as Mr. Nason has shown, in Chapter V. of this report, on the General Geology, it is probable that the details of the sections of these series will also undergo considerable modification. Other studies, besides those prosecuted by Mr. Nason, go to show that the division of the series into First, Second, Third and Fourth Magnesian Limestone, separated by persistent sandstone beds, will not hold. In a paper soon to be published in the *American Journal of Science*, the writer shows that the classification of the members of the so-called "Magnesian Series," in St. Francois and Ste. Genevieve counties, was radically wrong. Mr. Nason has found it necessary, for the purposes of his report, and as indicative of the changes necessary, to apply two names to members of the Ozark series. These are the "Roubidoux Sandstone" and the "Gasconade Limestone." These names express his classification of the rocks. They are accepted here provisionally until more extended work than he had opportunity to engage in, shall demonstrate their entire tenability.

Concerning the porphyry ores of Pilot Knob, Mr. Nason has reached

certain conclusions at variance with the results expressed concerning the origin of the porphyries by Mr. Haworth in Bulletin No. 5 of this Survey. During the past summer a conference and joint excursion to this field was arranged for. The party consisted of Prof. C. R. Van Hise. Prof. Wm. B. Potter. Mr. Nason. Prof. Haworth and the writer. A result of this trip and the consequent discussion on the ground was the yielding. by Mr. Haworth. of his position with reference to the origin of the porphyry conglomerates. iron ores and other immediately associated beds. occurring at the summit of Pilot Knob and at a few other localities in the immediate vicinity. Mr. Haworth now concedes that the evidence favors the conclusion that these beds are of sedimentary origin rather than of igneous origin as previously advocated by him.

As is frequently referred to and explained at different places in the following Report, it has been absolutely impossible to reach, examine and report upon all the iron ore localities in the State. during the brief period and with the small means allotted to the work. The area is too vast; the occurrences are too numerous. Effort has been made to direct attention merely to the principal areas and localities; to describe types and emphasize principles rather than to include exhaustive details. It is, however, nevertheless true. that. in many sections of the iron regions of the State, detailed work could be advantageously prosecuted, and it is the intention of the Survey to prepare in the future, as supplementary to this report. a series of topographic and geologic maps of important areas in the iron ore region. upon which shall be located all the various iron ore deposits, as well as other occurrences of economic value. A detailed report will accompany each of these sheets. describing everything of interest.

The map attached at the end of this report is intended primarily to show the geologic and geographic distribution of iron ores. In addition, however, it is issued as a provisional geological map of the State. It embodies the results of the work of the several Geological Surveys of the State up to date. It is the intention to issue similar maps with each successive volume of publications, each one to express the results of the most recent work.

Mr. Nason, in his preface. has considerately expressed his indebtedness to various gentlemen for assistance in the prosecution of his work. I take pleasure in joining with him here in an expression of gratitude to the citizens of the State who have so courteously assisted and entertained him. I especially wish to acknowledge Prof. Wm. B. Potter's assistance in the contribution of data and in the revision of the chapter on the porphyry ores. To Mr. Geo. H. Nettleton and to Mr. Louis

Houck we are particularly indebted for assistance rendered in the prosecution of the work along the lines of their roads. Mr. Geo. C. Smith, assistant general manager of the Missouri Pacific system, has also extended us many favors, and to the St. Louis and San Francisco Ry. we are similarly under obligations.

In the preparation of the Statistical Sketch, Appendix B, we received particularly valuable assistance from Mr. E. B. Sankey of Salem, Messrs. T. T. Lewis, E. A. Hitchcock and Wm. B. Potter of St. Louis; from Messrs. J. L. Buskett and Wm. Kelley of Rolla, and from Mr. Wm. James and his book-keeper, Mr. Bacon, of St. James.

In the proof-reading of this report Mr. J. D. Robertson has rendered much assistance, and he has also prepared the General Index at the end; the Geographical Index was prepared by Mr. E. H. Lonsdale. Such literary defects and errata as exist in this volume must be attributed in large part to the unavoidable haste with which the work was put into print.

I transmit this report with the feeling that it is a valuable and serviceable contribution to the literature of our iron ores, and with the hope that it may directly assist in the resuscitation of the iron industry of the State.

Very respectfully submitted,

ARTHUR WINSLOW,

State Geologist.

PREFACE.

In making a report on the iron ores of Missouri, one is, at the very outset, confronted with a difficulty of no little magnitude. In round numbers, what may be called the iron-producing belt covers an area of 30,000 square miles. This includes, 1st, the porphyry districts; 2d, the specular ore district; 3d, the limonite ore district; 4th, the bedded red hematite district, and 5th, the bog ore district. This last has had no definite boundaries. In forming an idea of the value of any ore deposits one must be largely influenced by the knowledge which may be acquired from deposits which have been worked in the past. No surface prospect, however promising, can give definite and reliable data upon which to base calculations as to extent, and, consequently, value. In other words, surface indications give only two dimensions; the third dimension which is invaluable can only be gained either from actual trial of the locality in question, or by analogy from the inspection of similar deposits which have been worked. In the great area given above there are at present only the following workings: two localities in the porphyry ore district, four in the specular ore district, one in the great limonite district, and in the red hematite district not a single one. The reasons for this state of inactivity are various, but as these have been pointed out in the appended reports on the various districts they will not be touched upon here. The difficulties which this condition entails upon the worker in such fields can only be fully appreciated by one who has had experience in such work.

Another obstacle to study which mining districts generally present, and the Missouri iron district in particular, is inaccessibility, the lack of railroads, the lack of good public roads, the inevitable concomitants of a scattered population, make the expenditure of a great amount of time absolutely unavoidable. Yet this difficulty has been largely obviated, or at least obviated to a greater degree than would at first seem possible, by the hearty and intelligent co-operation of the citizens of the iron ore district.

Considering these difficulties, and the limited time which could reasonably be placed at the disposal of the writer for this work, the following plan was devised and carried out so far as practicable. ..f attempting a detailed examination of each township, to study

in a general way, 1st, the modes of occurrences; 2d, the characteristics of the ores; 3d, the geographical distributions, the results of these operations resulted in the division of the limonite ore district into the Ozark district, the Osage district and the Mississippi district. These districts are not exactly outlined, this is impossible, but they indicate, in general, a distinct geographical distribution, and form convenient points from which to work. The idea has been to distribute the time allowed in the following manner. To give the greatest amount of time to points practically untouched in previous surveys, though controlled by the promise of iron ore in a given district: second, to distribute the remaining time as seemed best to serve the objects of a general report upon the iron ore of the whole State. By consulting the "Preliminary Map showing the Distribution of Iron Ores of Missouri" by Dr. Adolph Schmidt, Geological Survey of Missouri, 1872, it will be seen that considerable work was done on the limonites on the Belmont branch of the Iron Mountain railway and on the middle Osage river. The deposits there pointed out are as yet hardly touched, the Osage deposits especially, and attention has thus been called here to these localities as possible ore fields.

The whole tier of counties along and immediately above the Arkansas border from and including Stoddard county to Taney county was hardly touched. There are ten counties and only six localities reported. The work of the Survey shows this field to be at least as productive as any in the State, and consequently much time has been devoted to it. Even the most conscientious effort to locate every outcrop of iron ore, would in the end fail in the present state of development of the country. It has not, therefore, been attempted. Enough work has been done to prove that limonite ore exists in sufficient quantity to warrant the erection of local furnaces for its smelting and that other conditions are favorable for such an enterprise. This fact has been enlarged upon in the report. The location of ore deposits that has been done means, however, more than the mere fixing of these outcrops alone. One outcrop points certainly to others, neither now located nor reported, and the particular aim of the work done has been to point the direction in which others may be confidently looked for.

In the porphyry ore regions there is little use in minute examinations. The high grade of the ores and their accessibility to markets has stimulated private research to such a degree that probably every outcrop is known. Moreover, the detailed study which Prof. Haworth, with his assistants, has pursued, would inevitably have resulted in the discovery of such deposits had they existed. This careful study has resulted in

a discouraging, or at least a negative state of affairs. No new localities have been discovered. Attention in this field has, therefore, been confined to a careful study of the great deposits of Iron Mountain and Pilot Knob, to the probable conditions of their origin, and to the probabilities of the existence of other deposits now hidden from sight. The conclusions reached from this course of investigation are not capable of exact verification without considerable expense, but it is earnestly believed that prospecting along the lines laid down in the following report will, in many cases, be successful.

The same method has been pursued in the specular ore field in the sandstone region. Here, owing to the greater number of deposits which are now being worked or which have been worked, data of a much more satisfactory nature has been available. The conditions of occurrence and mode of deposition are seen with what seems to be unmistakable clearness. Basing his conclusions on the facts thus obtained, the writer has little hesitation in hazarding the prediction that the future of this district is at least as bright as its past has been.

The red hematite district has never been brought into notice as an iron-producing belt. Some exploring has been done in Callaway and Henry counties. The work has shown the beds to be thin and rather uncertain. Some of the beds could be worked with profit if a furnace were near by, but there is not in this field a promise of ore sufficient to warrant a plant's being erected. Enough work has been done in this field to establish the fact that the ores are of good quality, and that they are bedded deposits.

To sum up briefly the foregoing statements, it has been the aim of the Survey to establish districts in which iron ores were most abundant; to get at the nature of the deposit in order that subsequent prospecting might be done in the most intelligent manner, and to determine if conditions were favorable to the establishment of local smelting works. The result has been gratifying, for even with the most conservative estimates the question has an affirmative answer.

In the prosecution of the work on the iron ores the writer is greatly indebted to the State Geologist for his cordial support in the work as well as for direct and valuable assistance in many ways and especially in the preparation of this report. Editorial supervision is always a wearisome and oftentimes a thankless task, and it is with pleasure that I acknowledge my indebtedness for this assistance. In the field many have given such personal assistance as not only to materially forward the work, but to make the work itself a pleasure. The writer wishes to tender his cordial thanks to Prof. W. B. Potter, of St. Louis; Mr. Geo.

H. Nettleton, president of the K. C. M. and B. R. R., of Kansas City; Dr. J. H. Britts, of Clinton; Mr. E. L. Foote, superintendent of Sligo Furnace; Louis Houck, Esq., Cape Girardeau, president of St. L., C., G. and Ft. S. R. R.; J. B. White, Esq., general manager Missouri Lumber & Mining Co., Grandin; Capt. John Halstead, West Plains; Mr. David Carson, West Plains; Dr. J. E. Mosley, Alton; Messrs. Sanky, Salem; Mr. E. A. Kimmel, of Cape Girardeau; Mr. H. W. Hickman, Puxico, Stoddard Co.; Dr. Taylor, Browniugton; Mr. L. W. Munsell, Eminence; Mr. E. Y. Gannett, Nelson. This list could be indefinitely extended were the writer to mention every one to whom he is indebted for kind attentions. It is a matter of no little pleasure to acknowledge the cordial manner in which he has been received.

During the field season of 1892 Mr. E. H. Lonsdale has assisted me, both in the field and in the preparation of the report. The chapter on the "Special Description of Iron Deposits" is almost exclusively his work; it is with pleasure that I acknowledge his assistance. To Mr. J. D. Robertson, of the Survey, I am indebted for many of the drawings in the accompanying text and I gladly take this opportunity of acknowledging the same. Mr. A. Schmidt has reproduced many of the photographs and these are credited to him in the body of the report.

F. L. N.

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PART I.

THE IRON ORES OF MISSOURI.

A general discussion and description of the various ores and of the geology of the regions in which they occur.

THE IRON ORES OF MISSOURI.

BY FRANK L. NASON.

CHAPTER I.

INTRODUCTION.

THE ORES OF IRON.

THE FORMS IN WHICH IRON OCCURS—THE ORES OF IRON—THE RELATIVE VALUES OF IRON ORES.

THE FORMS IN WHICH IRON OCCURS.

Iron is one of the most widely distributed metals. It rarely occurs native or in the metallic state, but is generally combined with oxygen or some other non-metallic element. In the native state it is found in meteorites in large masses, and in grains in eruptive rocks. The nativemetal is so rare, however, that there is no need of further mention of it in a work treating of the sources of iron for economic uses.

Rarity of occurrence of native iron.

Iron combines with sulphur as a sulphide and is then known as iron pyrites (often mistaken for gold on account of its yellow color), and, in the form of a sulphate, as copperas. It also combines with arsenic, phosphorus, silica, etc. In the forms of silicates and hydrous oxides (oxide of iron combined with water) and anhydrous oxides it forms the coloring matter of rocks and soil.

Combination of iron with other elements

THE ORES OF IRON.

With the exception of metallic iron all of the compounds above noted are, properly speaking, ores of iron, but technically they are not. In practice an ore of iron is a chemical combination of the metal or element iron with (a) oxygen

What constitutes an ore of iron.

alone, (b) with oxygen and water, (c) with carbonic acid. A rich ore is one which runs from fifty-five per cent. up; a lean ore is one in which other substances are mechanically mixed, thus reducing the percentage of iron. There is no fixed limit to lean ores except that of profitable working. This limit varies with the market demand for iron.

Compounds of iron not ores.

The sulphide (iron pyrites) or the sulphate (copperas), green vitriol, are worthless as sources of iron, since the sulphur which they contain is very injurious to the metal, and it is quite impossible to get rid of it. Iron combined with phosphorus is also worthless for similar reasons, viz., the phosphorus injures the metal and is very difficult of removal. In addition to these facts other reasons exist why these compounds should be excluded from the list of iron ores. In the first place, they rarely, with the exception of iron pyrites and arsenical iron pyrites, exist in large deposits; and, in the second place, the percentage of iron is so low as to preclude the possibility of working them, even were they abundant and were the elements with which the iron is combined harmless to the metal.

Practically, therefore, the commercial source of iron is limited to three classes of iron ores, which are as follows: anhydrous oxides, hydrous oxides and carbonates. These ores may be presented in the following tabular form: —

TABLE I.

Anhydrous oxides.	Magnetite.	Magnetic iron ore.
		Magnetic titanic iron ore
		Franklinite.
	Hematite.	Specular.
		Red hematite.
		Red ochers.
Hydrous oxides.	Limonites or Brown hematite.	Stalactitic or "pipe ores."
		Compact earthy ores.
		Porous or Bog ores.
		Colored ochers, not red

Carbonates.	Siderite or Spathic ores.	Ordinary brown carbonate. Clay iron stone. Black Band.

Putting this table in another form it will show the comparative values of each of these ores according to the amount of metallic iron which each is capable of yielding.

TABLE II.

Anhydrous oxides.	Magnetite=$Fe_3\ O_4$=		Metallic iron	72.4 per cent.
			Oxygen	27.6 "
	Hematite=$Fe_2\ O_3$=		Metallic iron	70. "
			Oxygen	30. "
Hydrous oxides.	Limonite or Brown Hematite.	2 $Fe_2\ O_3$+ 3 $H_2\ O$=	Metallic iron	59.92 "
			Oxygen	25.68 "
			Water	14.40 "
Carbonate=	Siderite or Spathic ore	=Fe CO_3=	Metallic iron	48.30 "
			Oxygen	13 80 "
			Carbon Dioxide	37.90 "

In other words a ton of 2,000 pounds will yield of metallic iron—

Magnetite	1,448	lbs.
Hematite	1,400	"
Limonite	1,198.4	"
Carbonate	966	"

Theoretical yield of metallic iron from the principal ores.

These are theoretical yields from theoretically pure ores. But it must be borne in mind that no furnace yields the full percentage of iron that is in the ores, and that practically there are no pure iron ores of any kind.

The Magnetites. In the light of this last statement, let us examine Table I. In this table under "Magnetite," we find "Magnetic iron ore," "Magnetic titanic iron ore," and "Franklinite." This means simply that magnetite is frequently rendered impure by the admixture of titanic acid; and, in the case of Franklinite, a part of the iron is replaced by zinc and manganese. These ores usually occur interbedded with crystal-

line rocks, such as gneiss or mica schists; and, mixed with the ore body, oftentimes, there is much of the adjacent rock together with other minerals, such as quartz, feldspar, hornblende, etc.

Impurities of magnetic iron ores.

It is very evident, then, that in mining ores of this nature a ton of so-called ore will contain rock and minerals of a foreign nature and, in proportion as this foreign admixture increases, the percentage of iron is diminished. In the case of magnetite, therefore, the percentage of iron is commonly diminished in two ways. First, by a replacement of a part of the iron by some other metal such as zinc or manganese, or by some non-metallic element such as phosphorus, sulphur or titanic acid; and secondly, by admixture with the ore body of minerals like quartz, feldspar, hornblende, apatite, etc. Magnetites are uniformly black and are attracted by a magnet.

Impurities of hematites.

The Hematites. Hematite ore is less apt than magnetite to have, as mechanical impurities, minerals like feldspar, hornblende, mica, etc. It is quite as apt, though, to have phosphorus and sulphur, and it occasionally has titanic acid. This is true of the specular hematite. The red hematites occurring, as they generally do, in rocks less crystalline than either the magnetites or the specular ores, are also less apt to have, as mechanical impurities, crystallized minerals, excepting carbonate of lime. Sand and clay are much more common, and the ore has more of an earthy appearance. Phosphorus and sulphur also occur. Where the red hematite occurs in loose friable masses, or if moistened feels greasy and free from grit, it is known as red ocher or red paint. Hematite is always to be distinguished by its color, even when in the mass it appears blue or black, its powder is cherry red.

The Limonites. The limonites present by far the widest range in form, mode of occurrence and color, of all the iron ores. Both hematite and magnetite have distinct crystalline forms. Magnetite is always crystalline, and the same can be said of the blue or black hematite, while the earthy or more crystalline varieties of hematite are always red. Limonite has no crystalline forms of its own and hardly a distinctive color.

What is known as "pipe ore" is limonite in the form of long,

usually slender tubes. These tubes generally have a small hole reaching from end to end, but this is usually so choked with ocher or other substance as to be hardly discernible. These tubes or "pipes" occur singly or in great bunches or masses so compactly connected together as to present the appearance of a solid mass rather than of a bundle of distinct pipes. The pipe ores are without exception formed as pendants from the roofs of caves, or are built up from the bottom exactly in the same manner as stalactites of lime are formed in limestone caves. Pipe ores are usually the purest of all the limonite ores. The compact earthy limonites have the appearance of a solid rock, and are usually very pure, but are sometimes mixed with fine sand and clay. They occur in large beds or layers mixed with loose ocherous ores and clays. The porous or bog ores are the most impure of all the limonite ores. They usually have the appearance of pumice stone, except in color. That is they are porous or cellular and they carry a large percentage of fine sand and clay, thus reducing largely the percentage of iron.

Impurities in the various forms of limonite ores.

The above constitute the principal varieties of the forms of limonite. This class of iron ores carries the lowest percentage of iron, with one exception, of any worked ore. As impurities they rarely have any crystallized minerals such as quartz, feldspar, etc.; but they usually carry a high per cent. of silica, in the form of chert or flint, fine or coarse sand, sometimes both, and alumina in the form of clay. The limonites usually carry rather large amounts of phosphorus, and sulphur is generally present, but rarely in sufficient quantities to prevent the use of the ore. To these must be added from 11 to 14 per cent. of water, which is an essential constituent of the mineral.

Value of limonites.

Owing to the low percentage of iron in limonites, even when comparatively pure, they are not so sought for as are the magnetites and red hematites or specular ores. They are rarely shipped to great distances, and, in the localities where the richer ores are found, they would not be used at all were it not for the fact that their open or porous structure causes them to be very easily reduced in a furnace.

The Carbonates. The carbonates of iron carry the lowest per cent. of iron of any worked ore, even when pure. They are of

comparatively rare occurence in workable deposits in this country. Bulletin No. 113 of the Eleventh Census of the U. S. shows that the carbonates constituted only 2.98 per cent. of the 14,518,041 tons of iron ore mined in the year 1889. The principal varieties of siderite, the names of which are of no great significance, are "White horse" for a nearly pure carbonate of iron; "Clay iron-stone" for a very impure carbonate, the impurity being principally clay; and "Black band" for a carbonate of iron carrying much carbonaceous or coaly matter. This coaly matter is often so abundant that, by the addition of but a slight amount of fuel, the ores are self-roasting.

Carbonate iron ores; their abundance; their varieties.

THE RELATIVE VALUES OF IRON ORES.

From the foregoing pages it will be gathered that the value of iron ores, according to the amount of metallic iron which they carry, is as follows: —

Table of comparative values of iron ores.

First. Magnetite.
Second. Hematite (red, blue or black);
Third. Limonite, or brown hematite;
Fourth. Siderite, or spathic iron.

This is the order of succession of pure ores; yet impurities are so often present that, in a given locality, an iron ore of a normally inferior rank often contains more iron than one which ranks higher in the above list. Thus, in Alabama, red hematite ores are used, which, instead of the theoretical 70 per cent. of iron, yield only 30.5 per cent. to 51.6 per cent. of metallic iron. In New Jersey 51 to 55 per cent. magnetic iron ores are used when pure magnetite is capable of yielding 72.4 per cent. of metallic iron. In still other places iron ores which carry from 55 per cent. of metallic iron and upwards are not used on account of the high per cent. of phosphorus, sulphur or titanic acid present.

How impurities alter the relative values of ores.

The value of an iron ore does not, therefore, depend upon any one thing, but upon a combination of circumstances which will be pointed out in the following paragraphs. The principal factors in determining values are —

Factors determining the value.

1. The amount of metallic iron;

2. The freedom from deleterious substances, principally phosphorus, sulphur and titanic acid;

3. The proximity to markets or smelting points.

Examining the above points a little more in detail we find (a) that there is no fixed price for iron ores of any class, but that the price varies from year to year or oftener.

1. *The Influence of the Percentage of Iron.* Other things being equal, the price of iron ore is determined by the amount of metallic iron which it carries, reckoned by units; *i. e.*, a ton of 2,240 lbs. is divided into 100 parts. If the ore is hematite and absolutely pure, 70 of these parts or units are metallic iron. If, now, iron is selling at six cents per unit, the ton of 2,240 lbs. is worth $4.20. (b) If an iron ore, through impurities, drops much below 60 per cent., it cannot be shipped to any great distance, as is shown by the figures of the Eleventh Census.

Influence of percentage of metallic iron.

2. *Influence of Deleterious Accessories.* (a) If phosphorus is present in amounts from 2 per cent. up, the iron ore is unfit for any purpose whatsoever, unless for mixture with an ore of a much lower percentage of phosphorus. Iron ores with phosphorus in the proportion of $\frac{1}{1000}$ or less (*i. e.*, 1 part of phosphorus to 1000 parts of iron), bring a little higher price, since such ores can be used for special purposes, such as the manufacture of Bessemer steel. (b) Sulphur present in quantities greater than 1 per cent. makes roasting necessary, thus adding to the cost of the ore. If the percentage of sulphur is not too great, however, and the percentage of iron is high, sulphur is not an insuperable objection. (c) Titanic acid present in quantities from 3 per cent. up renders an ore unfit for use on account of the extreme difficulty of fusion.

Influence of deleterious elements.

3. *The Influence of Proximity to Market.* Proximity to consuming points is another essential factor in determining the value of an iron ore. Proximity is a variable not a fixed term. A limonite carrying 55 per cent. of metallic iron will not bear transportation by rail four hundred miles, while a Bessemer hematite or a magnetite carrying from 60 to 65 per cent., or more, will stand transportation from one to three thousand miles, especially if the greater part of the distance is by water.

Value of ores affected by a proximity to market.

From what has been said, it is plain that not every iron-bear-

ing mineral can be classed properly as an iron ore, although strictly speaking it may be so, and that impurities, on the one hand, and distance from manufacturing centers on the other may further prevent the mining of iron ores, even when they are apparently abundant.

The Influence of Impurities on Product. But with even a consuming point near at hand, and with ore of good quality, the nature of the impurities associated with an ore has much to do with the use which is made of it. Dividing the common impurities into the classes, inert and deleterious, we have as:

Influence of impurities on the smelting of the ores.

Inert,	Silica; Alumina and other refractory minerals.
Deleterious,	Phosphorus; Titanic acid; Sulphur; Arsenic.

These impurities in iron ores determine the uses which can be made of them. At the present day, comparatively little wrought iron is made directly from the ore. Whatever kind of iron is ultimately intended, the first product is pig iron from the blast furnace. From pig iron as turned out from the blast furnace is made steel, wrought or merchant or forge iron, and cast, or foundry iron. Pig iron, then, as it comes from a furnace, may be rightly classed as:

Immediate product from the ores.

For steel,	Bessemer pig, Basic or open hearth pig.
For iron,	Forge iron, Foundry iron.

Steel is widely used at the present day, and is rapidly taking the place of iron in many structures. For rails, boilers and

plates, hulls of ships, bridges, girders and trusses and for heavy castings, but where great tenacity and strength and comparative lightness is required, steel is almost exclusively employed. By far the greatest amount of steel that is used to-day is produced by a process patented by Mr. Henry Bessemer of England. In order to make what is known as Bessemer pig, iron ore low in phosphorus must be used. The presence of silica even in a large proportion is not fatally objectionable since in the process this is almost wholly removed, while the proportion of phosphorus is slightly increased owing to the fact that none of the phosphorus is eliminated in the process, while the molten iron loses comparatively large amounts of silica, carbon and manganese and some iron. An iron ore, therefore, carrying much phosphorus, is worthless for Bessemer steel. The modification of the Bessemer process, known as the *Basic* Bessemer process, is one in which the lining of the crucible is limestone, or "basic" instead of "siliceous" or acid. By this means the phosphorus is completely eliminated, or at least reduced to a point where it no longer acts injuriously on the steel. The process is slower and more expensive than the original Bessemer process, and, as iron ore can be obtained in this country almost wholly free from phosphorus, it is but little used here.

Ores suitable for the production of Bessemer pig iron.

Another method of steel making from pig iron is known as the open hearth basic process. In this process the lining of the furnace is made from limestone, as in the basic Bessemer process, and the phosphorus combines with the limestone and passes off in the form of slag. This process, though, to be economical, requires an iron low in silicon, and thus the range of available ore is as restricted as in the case of the Bessemer process. Although the absence of phosphorus from the pig iron is not absolutely essential in this process of steel making, it is desirable to have it as low as is possible, and, in the few open hearth basic furnaces in this country, a low silicon Bessemer pig is frequently employed.

How the open hearth steel process differs from the Bessemer process.

There are other processes for making steel in which almost any workable ore can be used, but these processes are very slow, and it would be impossible to use them in practice.

It follows, then, that, for the present at least, an iron ore

must be low in phosphorus if it is to be made into steel. Steel though, however valuable it may be, is not the only desirable iron for structures. Wrought iron is generally cheaper than steel, cast iron is decidedly so, and there are many cases where these are even more suitable than steel. Phosphorus, which, as we have seen, renders iron ores quite unfit for steel, is by no means an undesirable element in certain varieties of castings. In all cases where light castings for ornamental work or light forms with little strength are needed, phosphorus is an almost indispensable ingredient. Its presence in cast iron renders the latter easily fusible, keeps it longer in the melted state, thus enabling it to fill delicate moulds in which a more sluggish iron would chill. In pig iron for such purposes 2.5 per cent. of phosphorus is by no means uncommon. Sulphur which is injurious in Bessemer pig iron is beneficial in foundry pig iron, in small quantities, increasing its strength very perceptibly. Silicon, derived from silica in the ore, is always present in pig iron. It is occasionally 20 per cent. of the iron. In this case it is injurious, very decidedly tending to weaken any castings made from it, yet in moderate amounts of from one to five per cent. or more it has little apparent effect.

Among the metals which are found in iron ores and in the pig iron made from them, some are injurious and some are beneficial. Manganese is the best known and is of the widest importance. An alloy of iron and manganese is known as Spiegle iron or Ferro-manganese, according to the proportion of manganese present. This alloy, however, is principally valuable in the manufacture of Bessemer steel, and thus, if much phosphorus is present, it also becomes worthless.

Wrought iron or bar iron is sometimes made directly from the ores of iron in Catalan and other forges, but the greater part is made from pig iron, by a process known as puddling. Wrought iron is the lowest in carbon, cast iron the highest, while steel stands between. Wrought iron has from .02 to .03 per cent. of carbon, while steel has from 1 per cent. to 1.8 per cent. Steel then is only a highly carbonized wrought iron. They have many points in common. Phosphorus and sulphur are alike injurious to them, as are also silicon, arsenic and antimony. Sulphur and

copper render both wrought iron and steel brittle and unforgable while hot, and phosphorus makes it weak and brittle while cold. In other words, sulphur makes wrought iron and steel *hot short* or *red short* and phosphorus makes them *cold short*.

Summing the effects of these impurities we find:

Substances injurious to steel and wrought iron:	Phosphorus; Sulphur; Silicon; Arsenic; Copper; Antimony, tin, etc.
Substances beneficial to cast iron, when in small quantities:	Phosphorus; Sulphur; Silicon; Vanadium.

From this it will be readily seen that while a given iron ore may not make steel rails it is well fitted to make car wheels. Or, to put it more generally, an iron ore quite unfitted to make steel or wrought iron may be eminently adapted to making castings for a wide variety of uses. And so, though a given ore may be of restricted use in some directions, its value may not be correspondingly impaired. Adaptability iron ores to various use

CHAPTER II.

THE IRON ORES OF MISSOURI.

THE CLASSES OF ORES—THE DISTRIBUTION OF THE ORES.

Two classes of iron ore found in Missouri.

The Classes of Ores. The iron ores of Missouri occupy an intermediate position in the table of values given on page 3 of this report. The rich magnetites and the lean siderites are practically unknown in the State. Even among the porphyries and granites, where magnetite is usually found in disseminated grains, there is hardly a trace. Siderite, which is usually characteristic of Coal Measures, if not of older formations, exists in name only. Several thin seams, an inch or so in thickness, have been found in the Coal Measures, but this far they have been without commercial significance. "Black band," "white horse," and "clay iron-stone" are practically unknown. There are left then, two ores, hematite and limonite. These two ores have given the State its rank as an iron ore producer.

The hematites are by no means confined to Iron mountain and Pilot Knob, or in other words to the porphyry regions, but they are found in the Cambrian or Ozark series[1] of limestones and sandstones and in the Lower Carboniferous formations.

The limonites, however, are confined almost exclusively to the Ozark group of Cambrian age.

The following table shows the varieties of these ores which occur in the State.

[1] The term "Ozark Series," has been proposed by Prof. G. C. Broadhead as a substitute for the term "Magnesian limestones," previously used by him and others in the early reports of the Survey. See Amer. Geologist, Vol. VIII, No. 1, July, 1891. It is here adopted as the most appropriate name for that series of rocks. A. W.

Hematite.
- Coarse specular hematite or porphyry ore;
- Fine specular ore of the Ozark series of rocks;
- Vermilion ochers, or paint ores of the Ozark series of rocks;
- Earthy red hematite of the Lower Carboniferous formation;
- Kidney hematite of the Lower Carboniferous formation.

Ten varieties of the two classes recognized.

Limonite.
- Pipe iron ore;
- Compact limonite;
- Limonite pseudomorph after pyrite;
- Yellow and brown ocher paint ores;
- Bog iron ore.

The Distribution of the Ores. In regard to the distribution of the iron ores, a brief glance at the map accompanying this report will show that the various classes are confined by rather strict boundary lines. In addition, these boundary lines are somewhat concentric, and lie in the following manner. First, the great area occupied by the specular iron ores in the sandstone region is situated at nearly the crest or broad plateau-like apex of the Ozark mountains. Proceeding in any direction from this point these specular ores grow less distinct, as one passes from the sandstones to the limestones, and gradually we come to the great belt of limonites.

Specular ores of the sandstones.

The limonites are on and in the magnesian limestones, principally, and inclose this central area of specular iron on three sides quite effectually.[1] Wright and Greene counties break this ring.

The next band is that of the red hematites of the Lower Carboniferous formations. These ores are bedded and they are the only bedded deposits of iron yet found in Missouri except the beds of specular ore on Pilot Knob. They appear in promising outcrops in Callaway county. Following this junction line between the Cambrian series and the Carboniferous, through Ben-

Red hematites of the Lower Carboniferous.

[1] These limestones extend *under* the sandstones, but the sandstones being destroyed cause the appearance of a surrounding belt of limestone.

ton, Henry and Hickory counties, we find these bedded, red hematites quite persistent, but not in the same promising manner that we find them in Callaway county.

Another band, beginning also on the north and reaching to the west and to the south is that of the thin seams of carbonate iron found in the Coal Measures. As was mentioned in the beginning of this chapter, these ores are not considered abundant and hardly deserve to rank as forming a belt. Yet these lie in the Coal Measures and are characteristic deposits of that formation. So long, therefore, as it is not positively known that there are no workable deposits of this ore, it is hardly safe to predict that productive seams or beds will never be found. The Coal Measures of Missouri occupy a great territory, and at present it is comparatively little explored. But certainly, no great deposits have as yet been discovered. There is another class of iron deposits occurring in the Coal Measures but they will probably prove of no more value than the carbonates promise to be. Reference is made to the bog iron ores which are no doubt formed by chalybeate springs, which may now be active or may have long since ceased flowing. Such deposits were found near Clinton and Brownington, in Henry county, and also at Fray's mill, in Randolph county.

Coal Measure deposits of spathic iron ores.

Finally, there is one area of iron ores that has not been mentioned. This is the Archean area and it is unique for many reasons. The specular iron ores in porphyry are recognized as belonging to this age. Though they are in the midst of the limonite belt which surrounds the specular iron ores in the sandstone region, they are wholly distinct from these ores. These porphyry ores are unique, not in age alone, but also in that they evidently occur as vein deposits. In fact, prospecting with a diamond drill at Iron Mountain has shown that these veins run in the hard porphyry to depths of over one hundred feet. They are frequently no more than an inch in width; yet near the surface these veins, as mined, have been over one hundred feet in width.

Archæan area of specular ores.

With a certain degree of propriety, then, we can recognize the following classes of iron ore as occurring in Missouri, and each one is assignable to its special geological horizon, save that

of the limonites, which are never constant but represent a continual state of motion.

These classes, then, beginning with the oldest, are as follows :—

Various classes of iron ores occurring in Missouri and their geological horizons.

1. COARSE SPECULAR IRON ORE,
   Occurs in veins and conglomerate beds *in* and *on* the porphyry and in true beds at Pilot Knob.

2. FINE SPECULAR IRON ORE,
   Occurs in large pockets lying under the sandstones and on the limestones of the lower Cambrian.

3. LIMONITE IRON ORE,
   Occurs upon or in depressions of the Ozark limestones.
   (a) derived from the specular ores;
   (b) derived from the rotting of the rocks above;
   (c) derived from the Lower Carboniferous red hematites.

4. RED HEMATITE,
   Occurs bedded in the Lower Carboniferous rocks.

5. CARBONATE ORE,
   Occurs as siderite, bedded in the Coal Measure.

6. BOG IRON ORES,
   Derived from chalybeate springs.

In the following pages we shall take up these ores under the headings given above. In Part I will be included, in separate chapters, a general discussion of the Specular Iron Ores of the Porphyry Region, of the Red Hematites, of the Specular Ores of the Sandstone Region and of the Limonites; the two last being preceded by a chapter on the General Geology of the Ozark Uplift, in which regions these two classes of ore occur. Part II is a systematic description of the more important and most promising occurrences of Specular Ores in Sandstone, of Limonites and of Red Hematites, with especial emphasis on the Limonites; descriptions of the deposits of Specular Ores in Porphyry are contained in the chapter of Part I devoted to those ores, and are, hence, not repeated in Part II.

CHAPTER III.

THE SPECULAR IRON ORES OF THE PORPHYRY REGION.

INTRODUCTORY REMARKS — THE IRON ORES, THEIR MODES OF OCCURRENCE — THE IRON MOUNTAIN ORE DEPOSIT — PILOT KNOB — CEDAR HILL — SHEPHERD MOUNTAIN — CLARK'S MOUNTAIN — THE COMPOSITION OF THE SPECULAR ORES IN PORPHYRY — THE ORIGIN OF THE IRON ORES — SUMMARY.

INTRODUCTORY REMARKS.

Distribution of the Crystalline Rocks. In the southeastern part of Missouri, in St. Francois, Washington, Iron, Reynolds, Madison, Wayne and Shannon counties are extensive areas of crystalline rocks. Interesting as these rocks are, both from their isolated position with regard to other crystalline rocks and from their structural peculiarities, a wider interest has been aroused in them on account of the deposits of iron, worked for so many years, at Iron mountain and Pilot Knob. The apparent extent of these ore bodies when first discovered, as well as the remarkable purity of the ore, have made them famous. Unfortunately, unlike most other iron-producing crystalline rocks, the iron deposits of the porphyry are not co-extensive with the porphyry itself. In fact, the Iron mountain and Pilot Knob localities, the first to attract attention, have been, with a few minor exceptions, the only deposits of iron ore worked. Shepherd and Cedar mountains, near Pilot Knob, have each contributed to the total iron output of these localities, but the amount is utterly insignificant as compared with the first mentioned deposits.

res are con-d to South-ern Mis-ri.

The Topography. The topography of the porphyry region is picturesque in the extreme. Prof. Pumpelly speaks of the Archæan hills as " an archipelago of islands in the Lower Silurian strata which surround them as a whole, and separate them

pography is uresque.

from each other." The figure is an extremely happy one for the rocks of the younger formation cover all the inequalities of the older, and their very erosion leaves the valleys as they now exist at an almost uniform level.

Unlike the ridges and peaks of the so-called Ozark mountains the hills of porphyry and granite, have now, at least, no common level. They vary in height above the level of the surrounding Cambrian[1] rocks from one hundred feet, or even less, to five or six hundred feet. They rarely reach seventeen hundred feet above the level of the sea. Bearing in mind that the highest point of the Ozark mountains is about seventeen hundred feet above sea level, it can very easily be imagined that the Cambrian formation once covered even the highest of these hills. But as limestone and sandstone yield more readily to the attacks of denuding agents than do the refractory porphyries and granites, the area is gradually resuming its ancient topography, and we can easily picture to ourselves in a high degree of perfection, the general aspect of the country before the Cambrian seas covered it with the mantle of sedimentary rocks.

Formerly islands in a Cambrian sea, the hills still rise above the rocks of that age.

Whether we regard these porphyries and granites to be of sedimentary or igneous origin, they are now highly crystalline, and thus the contour of the hills, as the result of weathering, is much more irregular than that of the hills of the stratified limestones and sandstones. Pilot Knob, protected, as it is, by its compact cap of specular ore has a conical shape almost as regular as a volcanic cone, while others are more like long ridges and have their summits scolloped into rounding peaks of unequal heights. Although many of the hills were once undoubtedly precipitous, very few are so at present. The tendency of the rocks is to break or spall into irregular blocks. These blocks

The hills have a distinctive form and soil as compared with those of younger formations.

[1] The recent investigations of the Geological Survey are leading to the conclusion that the magnesian limestone and associated sandstone strata immediately about the Archæan hills of the Southeast are all of Cambrian age, rather than that part are Lower Silurian as has heretofore been held. Moreover, it is probable that the same applies to the rocks of the whole central portion of the Ozark uplift. Hence, in this report, these rocks are referred to as Cambrian and are so represented on the map. The evidence in support of this will be adduced in a forthcoming later publication. A. W.

yield but slowly to the weather and thus retain their irregular shapes for a long time and occasionally completely cover the side to near the summit. This of course precludes the formation of soil, and, so long as it lasts, the hills on one side are bare or, at best, are covered with a scant vegetation. This condition is, however, of comparatively rare occurrence. In general the easy slope of the hill retains either the soil resulting from the weathering of the crystalline rocks, or even the mantle of clayey soil left by the removal of the soluble constituents of the stratified rocks which once covered the former. Here the hills are covered with vegetation as flourishing as that of the limestone hills of the Ozarks, leaving only the general contour to distinguish them.

The porphyry rocks vary somewhat in color and texture.

Lithology. To the ordinary observer the porphyries are of a generally similar character. The differences most readily noticed are, first, color; second, texture. The color varies from a red to a dull brown. There seems to be no law governing the distribution of the red and brown varieties, both occurring in close connection in the same outcrop. The red porphyry, though, seems to have generally more of a bedded structure, while the more common brown makes up the greater bulk of the outcrops. In Shannon county and also in parts of Reynolds and St. Francois the surface color is gray, while a fresh or recently broken surface is inclined to be brown. In Shannon county, along Current river, the color is exclusively brown. Proximity to iron veins appears to modify both color and bedding, and the agencies which have produced the deposits of iron are probably responsible for much of this modification. The texture of the porphyry is more widely variable. Nearly every outcrop has places where the rock is almost aphanitic and in others the crystals of white feldspar are sometimes one fourth of an inch square. There are outcrops where the crystals are an inch square. The range in texture is, however, but little wider than is often found in metamorphosed gneisses.

[illegible] Though the porphyries generally, on weathered surfaces, have more the appearance of traps or green stones, the rock face being checked by numerous lines of fracture producing sharp angular spalls which cover the ground near the

foot of a cliff, there are other places where this structure appears to be almost wholly wanting.

In many places the porphyries have a decidedly bedded appearance.

Elsewhere there are strong indications of bedding. About three miles above Iron mountain on the Iron Mountain Railway there is an outcrop of porphyry which has a decidedly bedded appearance. The beds are four feet thick, some are less, and dip to the S. E. Figure 1 shows this apparent bedding.

FIG. 1. Apparent bedding in porphyry in Ry. cut, three miles north of Iron Mountain.

At Iron mountain the porphyry forming the foot wall at both the west and the east end of the mine has a decidedly bedded appearance. Here, however, the beds are so irregular that the appearance can as well be assigned to weathering from a massive rock as to deposition by water. At Pilot Knob, however, bedding structure occurs in such a way as to leave little room for doubt in the writer's mind as to the sedimentary origin of the porphyry in which the ore beds occur. The ore here rests on a porphyry conglomerate which passes gradually into a ferruginous slate, this into heavy beds of fine grained slaty ore. This is again capped by slaty ore much less pure, and this finally by a conglomerate which reaches to the summit of the Knob.

Associated Minerals. In spite of the fact that iron is found in workable deposits in only two localities, hematite is widely disseminated through both the granites and porphyries. In the granites it occurs in fine crystalline scales, which in many instances have been mistaken for lead or even silver by people who have found it. Just below Van Buren in Carter county and on the Current river is an outcrop of granite where this occurrence is well shown and several assays for silver have been made, but, of course, without favorable results. Veins of specular ore are rarely or never found in this rock. In the porphyry, however, not only does the hematite occur in disseminated grains, but frequently in veins as well. These veins are usually small and irregular and are often interrupted by quartz. At Shepherd mountain, Cedar hill and Iron mountain these veins are

Excepting iron the minerals of the porphyry are not abundant.

exposed at the surface of large proportions. At these places also the smaller veins occur sometimes at depths of two hundred feet or more as is shown by the diamond drill. Manganese also occurs in the porphyry rocks. In Shannon county, T. 28 N., R. 2 W., Sec. 31, veins of manganese, from three inches in thickness down to minute seams, occur of remarkable purity. Prof. Pumpelly, in his report,[1] mentions several bedded deposits of manganese occuring in porphyry. Several other localities have been discovered, but none of them have realized the hopes of the discoverers. The porphyries as well as the granites are generally remarkably free from other minerals. Apatite is occasionally found at Iron mountain in well defined crystals in connection with the iron ore. Quantities of hornblende, apparently of secondary origin, as well as crystals of quartz, garnet and also copper in the form of blue and green carbonates is sparingly found. In the porphyry region of Jack's Fork in Shannon county copper has been reported to occur quite extensively. Crystalline galena is also occasionally found. In the granite, veins filled with quartz occur frequently and occasionally crystals of great beauty are found.

Some manganese occurs.

Relations of Porphyries to Cambrian Rocks. The relation of the porphyries to the Cambrian rocks is very simple. Though there are porphyry knobs and ridges that rise high above the Cambrian strata, yet the floor upon which the latter rest is of porphyry or granite over a large area. Mining operations at Iron mountain show sandstone and limestone resting on the flanks of the porphyry mountain. Diamond drill holes at Pilot Knob, in the valleys between Pilot Knob and Shepherd mountain, Pilot Knob and Buzzard mountain show that, in these places, the overlying horizontal rocks from one to four hundred feet thick, rest upon a porphyry floor.

Cambrian rocks seen to be younger than granites and porphyries.

Along Current river between the mouth of Jack's Fork and Van Buren there are numerous outcrops of porphyry, many of which show the limestone lying on the uneven porphyry surface. In some places the limestone reaches under a porphyry ledge, being, of course, deposited under a former overhang-

[1] "Geological Survey of Missouri, 1872," Part I, pp. 20-25.

ing porphyry cliff. Along the river are often low porphyry hills completely encircled on the land side by limestone. Almost without exception when the limestone lies near the porphyry, there is a water course separating the two. The accompanying figures show the relations of the two rocks, at different points along the river below

FIG. 2. Sketch on Current river, showing limestone deposited under an overhanging porphyry cliff.

Relations of porphyry and limestone on Current river.

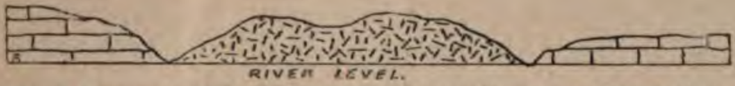

FIG. 3. Diagram showing the relation of porphyry to limestone on Current river.

Jack's Fork.

The granite hill below Van Buren is thus encircled by limestone hills with sandstone beds, the hills being four

FIG. 4. Relation of porphyry to limestone on Current river.

hundred and thirty feet high. At Doe Run and Mine La Motte work in the lead mines shows that granite underlies the lead-bearing rocks.

From the facts stated above, the conclusion is inevitable that the limestone series is younger than the porphyries and granites.

THE IRON ORES, THEIR MODES OF OCCURRENCE.

As has already been stated hematite, and, to a slight extent, magnetite occur in crystalline scales and grains throughout the porphyries and granites. In the granites especially the hematite is a very prominent constituent, the scales being readily visible to the unaided eye. Thus far, however, these rocks do not differ in this respect from many rocks both massive and stratified. Even in other rocks, massive and bedded, it is no uncommon thing to find occasional veins of hematite. At Iron mountain, Pilot Knob, Shepherd mountain and Cedar hill these veins are remarkably developed. At Iron mountain, in what is known as Big

Large veins of iron are found only in the porphyries.

mountain, the veins of hematite are from forty to sixty feet in thickness. As the more solid porphyry is reached these veins diminish in size down to one inch and less in thickness. In places these form a perfect net work in the solid porphyry. Drill cores two hundred feet or more in depth show that these veins exist even at that depth.

FIG. 5. Sketch illustrating a vein of specular ore in porphyry.

Veins much more irregular, but of considerable size are to be found on Cedar hill near Pilot Knob in Iron county. The adjoining cut[1] shows the nature of these veins. Workings subsequent to Prof. Pumpelly's report have failed to reveal large deposits. Larger veins on Shepherd mountain have been more extensively worked. On Pilot Knob the deposits in general are of a wholly different character as will be pointed out later on, but in the solid porphyry, which underlies the main ore bed, veins of hematite of small size are found. On the slopes of all the mountains above mentioned there are numerous boulders of specular ore. These in every case partake of the nature of the ore in the veins of the mountains on which they occur. There is no difficulty thus in assigning these boulders to their respective sources. At Iron mountain and Pilot Knob these boulder deposits have yielded great quantities of excellent ore, and such deposits at Iron mountain have not yet been exhausted. On Clark's mountain, in Wayne county, boulders of specular ore have been found in considerable abundance, but the attempts to find the mother vein have thus far failed.

The only bedded deposit is at Pilot Knob.

The source of these boulders is, of course, the veins of hematite which are yet found in the porphyry. The porphyry has rotted, leaving the veins standing in the form of dikes of iron ore. As the decomposed porphyry has washed away, these dikes are exposed to the weather, are broken up, and their fragments are rolled down the slopes of hill. These have been worn by the action of the rain and, probably, by water as well, into rounded or sub-angular boulders of ore. In places like Clark's mountain it may well be that the degradation of the porphyry

Boulders of hematite derived from weathered veins are often found.

[1] From the Report of the Geological Survey of Missouri, 1872, Part I, p. 19.

has proceeded to a point below the vein, thus leaving only scattered boulders of the ore, remnants of formerly existing veins.

THE IRON MOUNTAIN ORE DEPOSIT.

Passing from the general discussion of the iron ores in the porphyry rock, let us examine more minutely the more prominent of these deposits. One of the first reports written was by Dr. A. Litton of Washington University of St. Louis. His report gives us a very graphic picture of the deposits before extensive mining operations had begun. Dr. Schmidt's report in 1872 will also be drawn upon, as this shows us some very important phases of these deposits which have long since been obliterated by the progress of mining operations.

Dr. Litton's description of the Iron mountain deposit.

Early Description by Dr. Litton. In Prof. Swallow's Report of the Geological Survey of Missouri, published in 1855, Part II, p. 76, Dr. Litton writes as follows:—

"As we ascend the southwestern termination of the little Iron Mountain, we find it covered with soil and clay, with, now and then, the iron ore lying loose on the surface. In passing over the ridge connecting it with Iron Mountain proper, we find these angular and partially weatherworn pebbles and masses increasing in size, even until we reach its summit, where we find disconnected masses, many tons in weight and often six or eight feet in diameter. These are sometimes almost totally uncovered; but, at other points, are seen projecting out from the soil and clay with which they are partially covered. Nowhere, on the Iron Mountain, can we find any rock; and the masses of iron ore cannot be seen in place on the surface, but seem scattered irregularly, in confused masses."

Large quantities of surface ore were exposed.

"It is not until we leave the Iron Mountain, and begin to ascend the ridge of higher hills, with which it is connected on the east, the course of which is about northeast southwest, that we could find anything else than iron ore, and where we find the hill composed of feldspathic porphyry. According to Mr. Mersch, who had opportunities to examine at the most favorable seasons, this locality, there is a narrow wall connecting the mountain on the east with the main ridge, along the line of which

Passage from porphyry to iron bearing rock is sharp.

wall the iron ore and the porphyry are intermixed for a short distance; but to the east of which, the porphyry, and to the west of it the iron ore, are each found perfectly pure and unmixed."

"From surface indications, and from all explorations made, the whole of Iron Mountain seems to be a mass of iron ore."

The above description made by Dr. Litton gives one a very graphic idea of the Iron mountain of forty years ago. There is little reason to wonder at the estimates which were then made as to the inexhaustible supply which this deposit was supposed to contain, when we couple Dr. Litton's description of the surface appearance with the fact that the base of the mountain covers about five hundred acres and that the highest point of the mountain is about two hundred and fifty feet above the level of the railroad.

The removal of the mantle of boulder shows the mother veins.

Distribution of Vein Ore in the Porphyry. In 1872 the work of mining had progressed to a considerable extent, enough to show that the mantle of boulder ore did not extend to the base of the mountain undiminished in richness. The adjoining topographical sketch, Fig. 8, by Dr. Schmidt, shows graphically the hill over which the surface boulder ore was strewn, and the positions of the cuts in the veins are marked by the letters A, B, C, D, E, F, G, and H. From the positions of these cuts, which are opened up on a more or less continuous vein, the general direction of the main ore body is seen to be nearly due southeast. When first the boulder ore was removed from the summit of the mountain, it was seen that this had been derived from a solid bed or vein which was then for the first time exposed. This vein measured sixty feet across at its widest place. Instead, however, of holding this width downward for any depth, it soon divided into two independent veins. These veins varied in width from 12 to 18 feet. Fig. 7 shows the positions of the veins and

FIG. 6. Sketch of Iron mountain as it appeared in 1872. From Report 1873, p. 100.

their relations to the surrounding rocks. Flanking these veins on the southwest and the southeast are great masses of decomposed porphyry. The greater part of these bluffs are standing at the present time. They are com-

Character of veins.

FIG. 7. Section of the Big Vein at Iron mountain. Cut A, Fig. 6.

posed of porphyry which has decomposed *in situ*. As is often the case in the weathering of massive rocks there is here an apparent bedding structure. In addition to this weathering in layers the rock at first sight seems to be made up of rounded water-worn pebbles of porphyry. Examination shows that these apparent pebbles are of porphyry and that they break into concentric shells. The interstitial matter is also decomposed porphyry. This material is laminated and it is seen that the laminæ go entirely through the supposed pebbles. Further it is seen that this conglomeratic structure ceases very often from side to side or along the greater axes of the laminæ. The accompanying sketch shows the appearance of the conglomerate.

FIG. 8. Diagram illustrating the spheroidal weathering of porphyry.

Under the mine openings at the west side of the mountain, in fact in the foot wall of this ore body, the porphyry has a brecciated appearance. It seems to lie in beds which are more or less separated by bedding or parting planes. These parting planes divide the foot wall rock into irregularly shaped masses, bed-like in appearance, of four inches to several feet in thickness. The fragments of porphyry are comparatively fresh. The interstices are filled principally with a hard blue ore, with a coarse crystalline structure. Although the veins are very persistent, the filling matter is not constant. There are long spaces which are completely filled with light green crystals of the hornblende family. Crystals of milky quartz are also numerous. Apatite is more rarely found. Yet embedded in the solid ore

The foot wall of the Little mountain vein is a breccia.

FIG. 9. Illustrating brecciated foot wall at Iron mountain. Reduced by about one-twentieth.

are crystals of apatite ranging from acicular crystals to large prisms one-half of an inch in diameter. Near the surface these are represented almost wholly by hexagonal cavities in the ore. The accompanying Fig. 9 shows the appearance of this breccia.

Apatite found in the porphyry.

Cut B, Fig. 6, shows the relations of the veins which were exposed during the progress of the working in 1872. At that time, however, the veins were enclosed in the more decomposed porphyry. They were of a workable size, but these have now been entirely exhausted. The remaining veins have also diminished in size and, in the fresher porphyry, they have thinned out to a point where it is no longer profitable to work them.

FIG. 10. Showing veins of specular ore in Cut B, Fig. 6.

The workings show the relation of the veins to the porphyry.

Cuts C. C. and D, illustrated by Figs. 11 and 12, still further show the irregular distribution of these veins through the rock mass and, by comparison with the topographical sketch on p. 24, their relations to the main body of the mountain will be apparent. It is a fact worthy of notice that only the smaller veins of ore have been found to extend into the fresher porphyry.

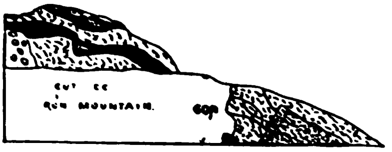

FIG. 11. Showing veins of ore in Cut C. C. of Fig. 6.

FIG. 12. Showing veins of ore in Cut D of Fig. 6.

Residuary Clays and Boulder Ores. The residuary clay, the "bluff" of the miners and the enclosed boulder ore is, with exceptions which will be mentioned, practically about the same as it was in the earlier days of Iron mountain. This clay is tough and deeply stained with iron. To one with a love of color, nothing can be more beautiful than the various shades, from deep vermillion to the soft creamy brown and yellow, of the less weathered portions of this clay. On the summit and slopes of Big mountain this richly colored clay is sparingly filled with blocks or boulders of iron ore of varying size. These blocks, though of remarkable purity, are not abundant enough to pay

The residuary clays enclose many boulders of ore.

for systematic working on the summit of the mountain. Lower down on the slopes, though, the mountain is completely flanked by a thick mantle of this clay which lies on top of the Cambrian rocks which also encircle the mountain. Inclosed in this clay are numerous smaller fragments of iron. These of themselves, are not of sufficient abundance to pay for working. Under the clay, however, and resting near the Silurian rocks is a bed of varying thickness composed almost wholly of fragments of iron. Mingled with the iron are numerous small irregular fragments of chert. This detrital deposit is now being systematically worked. The iron of course, came from the decomposed porphyry rock, while the chert must have come from a decomposed bed of Cambrian limestone. The enclosing clay is tough and bright red in color. The whole of this deposit, resting as it does upon Cambrian rocks, represents erosion and weathering since Cambrian time.

Bed of detrital ore is under the surface clay.

As has been stated, this mantle of clay or "bluff" to-day, is about the same as in 1872. But all that is left to indicate the position, size and shape of the veins of ore are the cuts in the more decomposed porphyry, as well as small ones which, on Big mountain, reach into the fresher rock. The only remnant of the great veins of 1872 is now being worked on Big mountain. The workings of to-day present quite a different phase.

Following down a lead on the west end of Little mountain a large body of comparatively undisturbed ore was found. This ore body dips steeply down on a foot wall of decomposed porphyry which is intersected by a complete network of small veins of iron ore. The entire length of this ore body measured on the slope is about 360 feet. The thickness of the vein measured from foot to hanging wall varies somewhat, but is between thirty and forty feet. The slope on the foot wall is nearly 40°. The immediate hanging wall is a mass of a probably pseudo-conglomeratic porphyry containing more or less iron or ore (see Fig. 8, p. 25). This hanging wall conforms very closely to the foot wall as to slope. Overlying this are the Cambrian rocks. These are unconformable to the ore body. They have a slight dip with the vein, but this may have been caused by the settling of the rocks owing to removal by solution of a part of

A large vein of ore is found on the west slope of Little mountain.

the limestone. The comparatively recent clays and boulder iron ore overlie all. The adjoining cut, Fig. 13, gives a fair

Section at Little mountain.

FIG. 13. Section of iron vein and overlying rock at Little mountain.

representation of the relations of the rocks to the ore body. Owing to the fact that the Cambrian rocks thin out on the slopes of the mountain no exact measurement of the thicknesses of the rocks can be given. In addition to this the individual beds thin out and thicken horizontally is such a way that a section correct in one locality would be incorrect at a distance of twenty feet. The location of this deposit is at cut H, on Dr. Schmidt's topographical map, p. 24.

The Little mountain vein is shown to be comparatively undisturbed.

From the fact that on the east side of the mountain there is a large deposit of boulder iron ore which underlies the Cambrian rocks, this last described vein at first thought might be considered as belonging to the same formation. It must, however, be considered as an undisturbed vein for the following reasons: The ore is comparatively solid, being only broken by seams such as are liable to occur in any rock. The ore body has a steeper dip than the slope of the mountain side. It ends abruptly at the bottom. It has a porphyry conglomerate as a cap rock or hanging wall which bears a close resemblance to a rock which has rotted in place. It is very safe to conclude then,

that this is an undisturbed vein such as were found on the summit of Big mountain.

FIG. 14. Section through Little and Big mountains, showing the relations of the porphyry to the younger rocks, and of the veins and conglomerate ore to the porphyry. From drawings of Iron mountain by Prof. Wm. P. Potter.

The section through Big and Little mountains.

As will be seen by looking at the topographical sketch map before referred to, all of the large veins were on Big mountain. It will further be noticed, by referring to the adjoining section (Fig. 14) through Big and Little mountains that the large conglomerate beds are at the eastern foot of Big mountain also. There is a bed of conglomerate which seems at first sight to be divided into two parts. The first, or upper part, is near F, on the topographical map (see Fig. 6. p. 24). It runs under the overlying Cambrian rocks at an angle of about 30°. From the mouth of the slope to the point where it is intersected by the vertical shaft is about 480 feet. The deposit does not seem to have been laid down on the flat surface of the mountain, but in a gorge or waterway down the slope. The thickest part of the bed from foot to hanging wall is about fifteen feet. This gradually thins out laterally towards the edges, giving a cross section of the bed of a roughly lenticular shape. It holds its size remarkably well longitudinally along its slope.

The deposit on the east side of Big mountain is not made up of iron boulders alone.

The ore body is not made up wholly of ore boulders, but there are found occasionally fragments of porphyry rock. The interstices between the boulders are filled with a bluish gray clay derived from the porphyry. The foot and hanging walls are related as follows: The foot wall a few feet below the actual contact of the ore is comparatively fresh porphyry which is filled with a net-work of veins of iron. The porphyry itself, as is usual, contains scales of

hematite. This solid bed passes gradually upwards into one which is less fresh and, from that, into a conglomeratic looking mass which has large fragments of solid ore. This is succeeded

Section of conglomerate ore at Big mountain.

Fig. 15. Section of first conglomerate bed at Big mountain.

by a regular conglomerate of iron ore, the interstitial spaces of which are filled with a bluish green or gray decomposed porphyry having little or no iron. The cap rock or hanging wall is

Section of conglomerate and limestone.

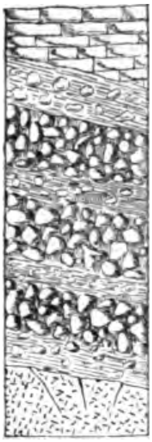

Fig. 16. Section showing relation of cong[illegible] bed to Cambrian limestone

nearly identical with the parting beds in the iron boulder beds, with the exception, that there are large boulders of porphyry clay with much quartz sand. The above section, Fig. 15, shows the relations of these alternate strata to the foot wall. This section is taken from one of the pillars of the slope near the mouth. Farther down the slope, towards the shaft, the ore bed is covered by a cap rock of limestone. The limestone, however, is separated from the ore body by the porphyry conglomerate, which does not seem to be conformable to the limestone, as the last section, Fig. 16, shows.

The second bouldeer deposit is but the continuation of the first deposit from the foot of the shaft eastward.

The second, or lower portion of the boulder deposit, or the part reaching from the foot of the shaft downwards, extends to the east from the foot of the upper portion and is partially separated from it by a tongue of Cambrian sandstone. The cap rock or hanging wall of the lower ore bed is of sandstone and the foot wall is of porphyry. From the relative positions of the two portions of the conglomerate bed to the sandstone, it would seem that the lower ore body was formed in a period of time somewhat antedating the Cambrian age. This deposit, covered for the most part by a mantle of porphyry clay, reached up to and upon the slope of the mountain. This was then covered by the Cambrian sandstone which partially cuts off this deposit from the upper one. The following, Fig. 17, shows the relation of these parts of the bed to each other and to the accompanying rocks. From the section it will be seen that

FIG. 17. Section showing the relations of the two conglomerate beds to each other.

a tongue of ore reaches from the upper portion over the sandstone but that this portion also continues down on the slope of the porphyry. The tongue of ore, the foot of the upper portion, is

much thicker than the head of the lower deposit and represents an accumulation of ore after the sandstone had formed. From the beginning of the lower deposit to the end, or rather to the breast of the present workings, the length is about one thousand two hundred feet. The two deposits very closely resemble each other in cross sections. The first deposit is, however, very uniform as to thickness along its entire length, while the second deposit in its thickest part is over forty feet.

The gangue of the second depo is, like the first deposit, porphyry detritus.

The gangue of the ore body in the second deposit is, like the first, entirely of porphyry detritus consisting of a hard indurated clay, which, in addition to fragments of hematite, has fragments of hard, red porphyry, in some instances looking like jasper. At the extreme end of the workings, as now known, these porphyry fragments are becoming more numerous and the iron correspondingly less. At the foot of the shaft the sandstone seems to rest directly upon the ore body. About 240 feet east of the shaft, the bed of indurated porphyry clay begins and increases in thickness towards the east.

So far as is known at present these are all of the great deposits of ore at Iron mountain. Vigorous prospecting, directed by a skilled geologist and engineer, is thoroughly testing the ground and it is to be hoped that this famous deposit may by this means have a renewed lease of life.

PILOT KNOB.

Dr. Litton describes the appearance of Pilot Knob when first opened.

Early Description of, by Dr. Litton. Pilot Knob is hardly less famous than Iron mountain. Promising almost greater things than did Iron mountain it has, however, never begun to realize the hopes of its operators. Dr. Litton, in speaking of this deposit, says:[1] "About six miles south and a little to the east of the Iron mountain, are other deposits of iron ore not less rich, and, in all probability, not less extensive. The rocks, near the base of Pilot Knob, are seldom seen in place; but when so, are of a dark gray color, present quite a siliceous and slaty or shaly character, and offer strong indications of stratification.

Report Geological Survey of Missouri, 1855, Part II, p. 79.

They are not, however, horizontal, but dip at an angle of twenty-five degrees to the southwest.[1] After ascending about 300 feet, the rock assumes more of a ferruginous character and, at the height of 440 feet, we find, on the north side of the mountain, an exposure of a heavy bed, or rather stratum of iron ore, about 273 feet in length and twenty-four feet in height, or thickness, apparently passing, parallel with the lower slaty rocks, and with the same dip, through the mountain, to the southwest. It is said that at still lower points than the above stratum, and beneath it, are other beds, interstratified with the siliceous rock, but at the time of my visit the side of the mountain wa so covered with debris and undergrowth that I didn't find these in place.

The ore stratum is twenty-four feet thick.

"Above the heavy stratum of iron ore, which is now quarried for smelting, the iron ore seems to be interstratified with the siliceous rock, even to the summit of the mountain."

The following sketch copied from Dr. Litton's report gives an idea of the ore deposit at Pilot Knob when it was first opened.

Sketch of the Knob in 1854.

FIG. 18. Sketch of Pilot Knob as it appeared when first opened.

In many of its physical aspects Pilot Knob differs from the porphyry hills in general. It is decidedly cone-shaped. It is almost isolated from the adjoining porphyry hills. It is con-

[1] The dip, according to Pumpelly, is, on an average, 13 degrees, and later workings make this evident.

nected on the east, however, with the higher hills by a low neck of porphyry which rises only about 200 feet above the surrounding Cambrian rocks.

The Character of the Ores. The ores of Pilot Knob are characteristically different from the other porphyry ores. The ores of Iron and Shepherd mountains and Cedar hill as well, are usually crystalline and massive in structure. The ores of Pilot Knob are, on the other hand, fine grained, almost aphanitic, and are universally slaty. As they occur in the mine these bands alternate with less rich orės or with thin bands of rock that carry so little iron as to give a gray streak and are thus totally unfit for smelting. In addition the ores were very low in phosphorus and such phosphorus as was present was distributed very uniformly. The Iron mountain ores, on the other hand, though in large part high grade Bessemer, contain a good deal of ore that is totally unfit for the manufacture of steel.

The ores of Pilot Knob, though very compact, are slaty in structure.

The Modes of Occurrence. There are three distinct modes of occurrence of iron at Pilot Knob. As usual there are veins of iron in the massive porphyry, but no veins of economic importance have been found.

Boulder Ores. Distributed over the slopes of the mountain are numerous fragments of boulder iron. These fragments have, on the north side of the mountain, been in such abundance as to enable them to be dug with profit. They are embedded in a tough red clay. One of these banks is at least thirty-five feet thick. From the nature and position of the boulders there is no difficulty in assigning their origin to the bedded deposits above them. Their slaty structure, close and fine grained, make this certain. Moreover they are always found *below* the outcrop of ore. Whether the boulder ore is the same as that which extends under the Cambrian rocks on the flanks of Pilot Knob is not certainly known.

There are boulder deposits on Pilot Knob which are evidently derived from the main bed.

The following section, Fig. 19, is taken north and south through the main body of ore on Pilot Knob, through the Cambrian rocks in the valley between the Knob and Buzzards mountain. It is from a report made in 1890, to the Pilot Knob Company, by Prof. Wm. B. Potter, and is published here with the author's permission.

The accompa[nying] section through Pil[ot] Knob is described.

The diamond drill holes (Nos. 48, 58, 49, 46 and 51) seem to indicate that the conglomerate ores which crop out in the open cut at 4 are continuous to the above mentioned point. In all five of these holes more or less iron ore was found and it is essentially of the same character as that found in the clays and resting *on* the porphyry rocks. As will be seen by consulting the figure, the sedimentary rocks nowhere extend below 200 feet in depth. It is a little remarkable that no sandstone occurs. The limestone, which is the ordinary magnesian, lies directly upon the porphyry detritus. Between this limestone and the solid porphyry lies the ore. Diamond drill holes have been bored covering, in a very thorough manner, an area of about 400,000 square feet. This prospecting has discovered a very considerable deposit of iron, but its quality does not seem to warrant its being worked at present. This ore deposit occupies a position analogous to the boulder deposit at Iron mountain, the points of difference being that the Iron mountain deposit has a hanging wall of sandstone instead of limestone and the iron is rich and remarkably low in phosphorus, while the Pilot Knob boulder ore is rather lean though low in phosphorus and sulphur. Numerous bore holes put down at the western foot of Pilot Knob have not discovered other boulder deposits.

FIG. 19. A cross section through Pilot Knob.

Pilot Knob ore body is evidently sedimentary in origin.

Massive Ores. It is in the main ore body of Pilot Knob, how ever, that the greatest interest centers. Whatever its origin it is unique among the porphyry ores of Missouri in that it is bedded and bears strong evidence of a sedimentary origin. It is a sheet of roughly pear-shaped outline with its longest axis running nearly north and south. It has an average dip to the southwest of thirteen degrees. Fig. 20, on the opposite page, from Bulletin No. 5, Geological Survey of Missouri, shows this. Fig. 21, below, from the same Bulletin, shows the position of the ore body with reference to the hill. From this

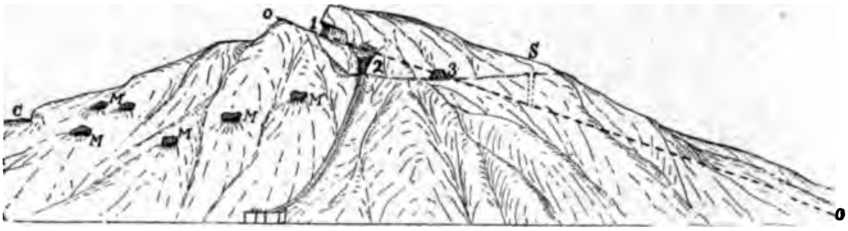

FIG. 21. Sketch of Pilot Knob showing the position of the ore bed, O–O, the cut on the north, the three tunnels Nos. 1, 2 and 3, the Simpson shaft, S, the cut east of the company's office, C, and several places where massive rocks are exposed, M.

last sketch it will be seen that this ore deposit is near the summit of the Knob. If one measures the outcrop of the ore

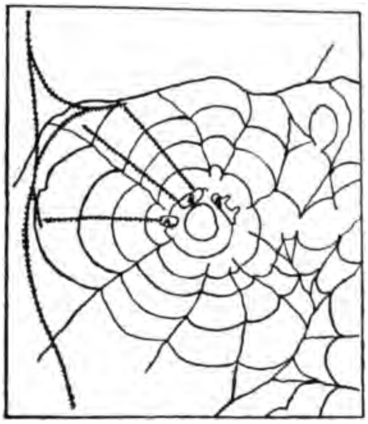

FIG. 22. A topographic sketch of Pilot Knob. A, B, and C represent cuts in the ore body. From Report 1872, p. 110.

Width of ore body irregular.

body on the arc of a circle represented by the cuts A, B, and C of Fig. 22, it will be found that the arc is nearly 1,000 feet long. From this arc to the southwestern extremity the width of the ore body increases slightly and then rapidly contracts until it is cut out by the country rock.

In bedded deposits generally the beds do not disappear in this manner, the bed usually grows either thinner until it is entirely replaced by the foot and hanging wall coming together, or " pinches

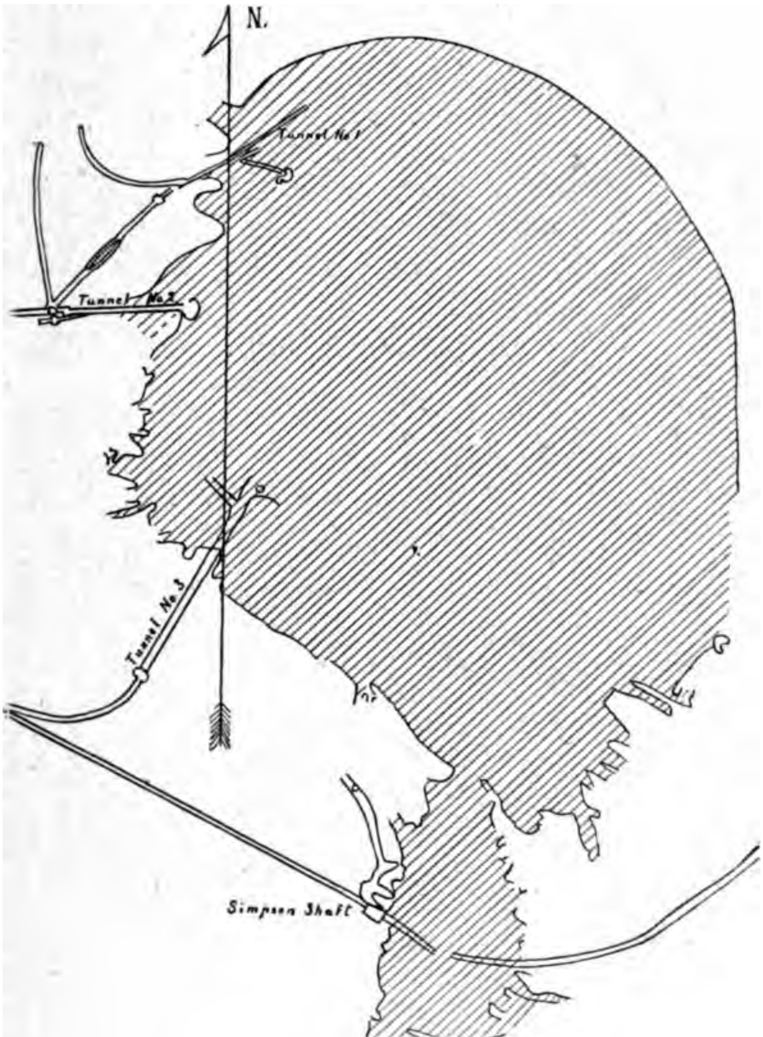

FIG. 20. A sketch map showing the outline and the extent of the ore bed on Pilot Knob. This ore bed reaches the surface on the north and north-east sides of the hill; but on the west, south-west and south it gradually changes into porphyry. The double line represents the tramways.

out" in the words of the miner, or it breaks up into thin strings of ore. At Pilot Knob the ore bed gradually grows leaner until it finally passes, by almost insensible gradation, into the hard, apparently unstratified porphyry. This is true for the southwestern side of the mine. On the northern and eastern sides the stratified ore body and its accompanying rocks come to the surface in a precipitous bluff.

Pilot Knob ore bed fades into the country rock.

As to the relations of the ore body to the foot and hanging walls the following section, Fig. 23, shows this quite accurately.

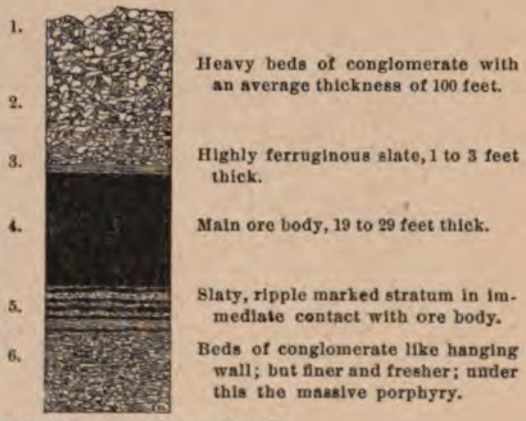

FIG. 23. Section of conglomerate and ore body of Pilot Knob.

Dimensions of the different strata are not given in every instance as they could not be measured owing to the falling in of the rocks.

The Conglomerates. A more detailed study of these beds may possibly give some clue to the origin of the conglomerates. The entire summit of the Knob is made up of a coarse conglomerate, the interstitial filling of which is composed of sericite scales, occasional grains of sand and a large percentage of hematite. Were it not for the large conglomerate pebbles this gangue would in most cases pass for a lean iron ore. It gives a red streak tinged with gray. There is, besides the sericite scales, a very fine constituent which is derived from the porphyry. The angular or subangular nodules which gives the rock its name, at first sight resemble quartzite. A close examination

The interstitial matter of the conglomerate is largely hematite.

FIG. 1.

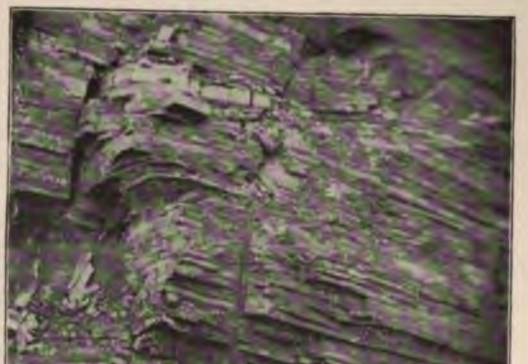

FIG. 2.

Views illustrating the slaty structure of the hanging wall at Pilot Knob.
Reproduced from photographs by F. L. N.

shows most of them to be soft and talcose or sericitic. They are not filled with iron as are the interstices and they are much lighter colored. Some are still hard enough to scratch steel. Close inspection shows, further, that these fragments have inclosed within them still other smaller angular fragments. In other words this breccia conglomerate is made up of a still older breccia.[1] Some of the boulders of the conglomerate as it exists now are a foot or more across. The annexed, Fig. 24, drawn from a photograph, shows the conglomerate in a typical form.

Breccia fragment are themselves brecciated.

FIG. 24. Sketch showing in detail the structure of the conglomerate above the ore body.

The Slaty and Jointage Structure. Towards the top of the ore bed the rock grows finer and shows a tendency to split into comparatively thin beds. The percentage of iron, however, does not increase to any extent. Fig. 2 of the opposite Plate I, from a photograph, shows this eminently slaty structure to a very marked degree. Fig. 1, of the same plate, also from a photograph, giving a general view of the beds above the ore, shows this characteristic more in the thickly bedded and coarser conglomerates. The blocks into which the joints divide the rocks are uniformly rectangular, or at least have little departure from a right angle. These blocks most closely resemble the joint structures seen in slate beds. The undermining of these beds by the removal of the ore body has caused the rocks to settle unevenly and the great cracks extending to the very summit of the mountain show the blocks very clearly.

Slaty structure and the jointing of the rocks and ore body resemble that of typical slates.

These blocks have been referred by Prof. E. Haworth, to the basaltic or columnar structure often seen in eruptive rocks.[2] This structure, however, differs very essentially from the basaltic forms. In the latter, the blocks or columns are often regularly hexagonal and are also pentagonal and sometimes triangular; the

The jointing is by different form, the basaltic structure in eruptive rocks.

[1] Attention has already been called to this fact by Prof. Haworth in Bulletin No. 5, p. 29, Geological Survey of Missouri, Jefferson City, 1891.

[2] Bulletin No. 5, p. 17, Geological Survey of Missouri, Jefferson City, 1891.

edges are usually sharp and the columns are rarely more than two feet in diameter, and break horizontally with a ball and socket joint. At Pilot Knob the columns are without exception rectangular. They split along planes with no trace of ball and socket, and the blocks often are forty feet across one of the edges. In a word, they have the appearance of being modeled after the jointed and slaty structure of slate beds rather than after the basaltic structure of eruptive rocks. This jointage extends into the ore body, though not in so marked a degree.

A thin bed of slate separates conglomerate and ore bed.

Separating this bed of conglomerate from the iron ore body proper, is a bed of slate. This slate is highly ferruginous, so high in iron ore in fact, that much of it was used as a lean ore. It is very fine grained and compact, and gives a red streak. The thickness could not be exactly ascertained.

The ore body is separated from the underlying conglomerate by a bed of alternating lean and rich slaty ore.

Under the iron ore body is another bed of slaty rock. The entire thickness of this is only about three or four feet. It lies in alternating bands of nearly pure slaty ore and leaner bands, and bands in which there is hardly sufficient iron to prevent a clear gray streak. The parting planes between the iron ore body and the slate proper are beautifully marked by what in a rock about the origin of which there is no question, would be called ripple marks. These are very plain and there would ordinarily be little doubt as to their origin. The broad surface also has what appear to be mud cracks. Much of the slaty ore has fine grains of silica, apparently sand.

The underlying conglomerates are fresher than the overlying.

The conglomerates below these slates are very similar in appearance to the ores above, save that they are not so coarse and are much fresher. These rest directly on the top of the massive porphyry of the Knob.

CEDAR HILL.

On Cedar hill, distant about one mile north of Pilot Knob, there is an irregular deposit of coarse, specular ore much like that which is found at Iron mountain. According to Prof. Pumpelly the porphyry of this hill has somewhat the appearance of a conglomerate. Only a few irregular outcrops of the vein were found and these were unprofitable to work. The conglomerates

of Cedar hill bear only a slight resemblance to those of Pilot Knob, but are, or seem to be, closely allied to those of Iron mountain. The conglomerate of that locality, it will be remembered, was supposed to be due to the weathering of the porphyry in the one case, or to crushing in another. The porphyry of the ore body on Cedar hill is much coarser in grain than that of Pilot Knob. From the position and size of the vein on Cedar hill it is not difficult to imagine that it is but the mere remnant of a once greater deposit.

The porphyry on Cedar hill is rather coarser grained than that of Pilot Knob.

SHEPHERD MOUNTAIN.

The ore deposits on Shepherd mountain, one mile to the west of Pilot Knob, are also undoubted veins. These veins are nearly east and west in strike. They have been quite extensively worked, but at a loss. On the western face the mountain has many rounded boulders of specular iron. This iron, mingled with fragments of porphyry, is embedded in a clay which is doubtless derived from the porphyry. These boulders are magnetic to an extraordinary degree. The deposits of Iron mountain and Pilot Knob have considerable magnetism, but none of them to the extent of those of Shepherd mountain. Practically this is the only point of difference between the ores of this deposit and others, excepting Pilot Knob. The porphyry of this mountain is coarse and shows no traces either of bedding or conglomeratic structure. Some of the rocks, however, especially those associated with vein ores, are beautifully banded.

The iron ore of Shepherd mountain is derived from veins and boulder ore.

The general appearance of the veins on Shepherd mountain as well as of the scattered fragments of ore lead to the conclusion that the summit of the mountain has been much eroded and that the vein has been worn down with it. No extensive prospecting with the object of testing the clays containing the boulders of iron has been done. If the vein is but the remnant of a once larger deposit, as seems to be he case, there should be boulder deposits of considerable magnitude buried here.

Shepherd mountain seems to have been much eroded.

Smaller deposits have been discovered in several other localities near Pilot Knob, but none have been found to be of commercial importance.

CLARK'S MOUNTAIN.

The veins from which the boulder ore on Clark's mountain was derived have not been found.

On Clark's mountain, in Wayne county, large boulders of specular ore have been found. An attempt to locate the vein from which these boulders were derived met with no success. Shafts were sunk in the clay in which the boulders were embedded, but they are reported not to have reached the porphyry. There is no certainty that this locality has been thoroughly explored. It was not visited, as no work had been done for several years, and whatever holes had been dug had long since fallen in.

This practically concludes what is to be said covering the specular ores in porphyry. Hardly any traces of ore have been found outside of the localities mentioned above. In the light of the facts learned about these deposits, we shall see later if there are any hopes that hidden deposits may be intelligently prospected for.

THE COMPOSITION OF THE SPECULAR ORES IN PORPHYRY.

Iron mountain and Pilot Knob are the principal mines.

The specular ores of the porphyry region are so widely and favorably known that little additional light will be thrown on the subject by the accompanying analyses. Iron mountain and Pilot Knob overshadow all other localities in this region, and justly so from the stand-point of production ; but other localities, unfortunately of limited extent, have yielded ores every way as desirable as the first named localities.

Iron mountain yields two decided grades of ore.

Iron Mountain Ores. Iron mountain yields two distinct classes of ores; the first are the vein deposits, or the ores which occur in veins in more or less solid porphyry; the second are the boulder and surface ores. These ores are also capable of another classification; first, ores low in phosphorus; second, ores high in phosphorus. So far as the boulder or surface ores are concerned they are almost universally low in phosphorus as the following analyses show: [1] —

[1] These analyses are taken from the Report of the Mo. Geological Survey, 1872; and from Tenth Census Report of the U. S., Vol. XV.

	(1) Per cent.	(2) Per cent.	(3) Per cent.	(4) Per cent.	(5) Per cent.
Metallic Iron......	66.93	59.06	65.57	64.67	62.84
Phosphorus.......	0.071	0.398	0.032	0.019	0.005
Phosphorus ratio..	0.106	0.674	0.049	0.029	0.008

Sample No. 1 was taken from the main vein at Iron mountain. It is free from quartz. There were no crystals of apatite visible to the unaided eye. Sample No. 2 is taken from the same vein but nearer the contact with the porphyry. This sample contained many crystals of apatite. No. 3 is a sample of surface ore. Nos. 4 and 5 are surface ores. No. 4 is taken from the surface near the main vein on Big mountain, while No. 5 is from the surface on the vein at Little mountain.

Other partial analyses of the Iron Mountain ores give: —

	(6) Per cent.	(7) Per cent.	(8) Per cent.
Metallic Iron..................................	67.75	66.60	68.63
Phosphorus..................................	0.052	0.057	0.031
Phosphorus ratio..........................	0.08	0.09	0.045

No. 6 is taken from surface ore on the western slope of the mountain and No. 8 from the surface on the southeastern slope.

The following analyses from 8a to 8p are published through the kindness of Prof. W. B. Potter, engineer of the Iron Mountain Company. They represent average analyses of the various ores shipped from Iron mountain from April 1, 1891, to March 31, 1892: —

	(8a) Per cent.	(8b) Per cent.	(8c) Per cent.	(8d) Per cent.	(8e) Per cent.	(8f) Per cent.	(8g) Per cent.	(8h) Per cent.
Silica.........	3.91	3.80	6.60	4.92	6.11	4.47	6.40	6.46
Metallic Iron..	65.68	66.51	62.19	63.79	63.08	65.13	62.50	62.81
Phosphorus...	0.026	0.020	0.028	0.093	0.060	0.034	0.038	0.063

	(8i) Per cent.	(8j) Per cent.	(8k) Per cent.	(8l) Per cent.	(8m) Per cent.	(8n) Per cent.	(8o) Per cent.	(8p) Per cent.
Silica.........	4.87	7.12	11.68	5.86	3.69	2.51	4.08	5.44
Metallic Iron..	63.68	61.45	55.22	63.00	59.64	66.80	65.75	64.12
Phosphorus...	0.070	0.105	0.026	0.389	0.226	0.058	0.095	0.013

8a. Surface jigged on, 2188 tons, average of 14 analyses.
8b Surface lump ore, 2378 tons, average of 15 analyses.
8c Soft jigged ore from Shaft No. 1, 9969 tons, average of 20 analyses.
8d Soft jigged ore from inclines Nos. 1 and 2, 7579 tons, average of 11 analyses.
8e Soft jigged ore from Shaft No. 1, Incline No. 1, 2450 tons, average of 4 analyses.
8f Soft lump ore from Shaft No. 1, 7536 tons, average of 25 analyses.
8g Soft jigged ore from Shaft No. 1, 14018 tons, average of 34 analyses.
8h Soft jigged ore from Shaft No. 1 and Incline No. 1, 921 tons, average of 3 analyses.
8i Soft jigged ore from Incline No. 2, 7008 tons, average of 27 analyses.
8j Furnace jigged ore, 3291 tons, average of 39 analyses.
8k No. 2 bluff ore from Shaft No. 2, 3327 tons, average of 14 analyses.
8l No. 2 bluff ore from upper S. E. mine, 693 tons, average of 4 analyses.
8m No. 2 bluff ore from W. and upper S. E. mine, 3177 tons, average of 8 analyses.
8n Soft lump ore from Incline No. 3, average of 4 analyses.
8o Soft lump ore from Incline No. 2, 90 tons, average of 1 analysis.
8p Special ore from Shaft No. 2, 1624 tons, average of 8 analyses.[1]

The solid veins of iron ore are more highly phosphatic than the boulder ores.

It will be seen from the above analyses that the ores mined from the solid veins are, in general, much more highly phosphatic than the surface ores. In fact many of the surface ores are almost wholly free from phosphorus. Although not really surface ore the bed of conglomerate which is now being mined on the eastern slope of the mountains is quite as free from phosphorus as are the surface ores proper. The reason is the same in both cases. The conglomerate ore, though now buried by the sediments of former Cambrian seas, were for a long time exposed to weathering agencies. These have attacked and almost wholly eliminated the more susceptible apatite leaving the ore almost wholly phosphorus free. Even were proof needed for this self evident explanation it is found in the fact that many of the surface ores show hexagonal cavities, the cavities from which apatite crystals have been removed. Still further, the

[1] In the above analyses reference is made to ores from various parts of the mountain. "Surface lump and surface jigged ores" are ores dug from the residual clays on the surface of the mountain. "Shaft No. 1" is the shaft sunk on the boulder ore deposit on the east side of the mountain. "Shaft No. 2" is sunk on the west side at Little mountain. "Incline No. 2" leads from the surface to Shaft No. 1. "Soft ore" is from the residual beds; "bluff ore" is from the solid veins.

unweathered ores taken from the veins have, in many cases, fresh crystals of apatite, showing conclusively the source of phosphorus in the ores. From the analyses given above it will be seen that there remains little or nothing to be added concerning the standing of the Iron mountain ores. Their high percentages of metallic iron give little room for silica and other inert impurities, while their low phosphorus causes them to rank high as Bessemer ores. The unweathered and phosphatic vein ores are a small per cent. of the total ore mined and shipped.

Pilot Knob Ores. The next ore body which has ranked high, both as a producer and as a high grade Bessemer ore, is that of Pilot Knob. Differing in many physical respects from the Iron mountain ores, they were almost as highly valued. The very low percentage of phosphorus and its remarkable even distribution went a long way to offset some of their more undesirable qualities. They were usually high in silica and their very dense, compact structure made them difficult to smelt. This was true not only of the ore mined from the bed, but to a great extent of the conglomerate ores now mined on the northern slope of the Knob. The conglomerate ores, however, though retaining their usual amounts of phosphorus, and silica are less refractory, for they have been much softened by weathering. Below are several analyses of the Pilot Knob ores: —

The evenly low percentage of phosphorus in the Pilot Knob ores makes them very desirable.

	(9) Per cent.	(10) Per cent.	(11) Per cent.	(12) Per cent.	(13) Per cent.	(14) Per cent.	(15) Per cent.
Metallic iron....	59.52	52.57	50.40	59.15	64.91	47.16	44.01
Phosphorus......	0.005	0.018	0.025	0.015	0.031	0.041	0.044
Phosphorus ratio.	0.008	0.034	0.050	0.025	0.050	0.090	0.100
Sulphur..........	0.020	0.320					

Sample No. 9 was taken from near the north-east end of the bed at Pilot Knob; No. 10 from the opposite end. No. 11 is taken from the upper bed near the hanging wall. No. 12 is taken from a more or less weathered surface near the opening of the mine. No. 13 is taken from a less weathered surface at the same place. No. 14 is taken from the lower strata of the bed; No. 15, from the same place but from the upper strata.

The following analyses, 15a to 15f, are also obtained through the kindness of Prof. W. B. Potter. No. 15a to 15d are average analyses for six months: —

	(15a) No. 1 ore. Per cent.	(15b) No. 2 ore. Per cent.
Metallic Iron	62.00	55.62
Phosphorus	0.017	0.022
Phosphoric Acid	0.032	0.051
Sulphur	0.028	0.038
Sulphuric Acid	0.075	0.096
Manganese Peroxide	0.15	0.22
Silica	13.25	18.53
Lime	0.18	0.22
Alumina	1.22	1.33

	(15c) Per cent.	(15d) Per cent.
Metallic Iron	66.83	43.03
Silica	3.62	30.65
Sulphur	0.07	0.098
Phosphorus	0.014	0.021

	(15e) Per cent.	(15f) Per cent.
Metallic Iron	61.72	58.110
Silica	9.810	17.020
Phosphorus	0.021	0.013
Manganese	trace	trace
Alumina	1.830	2.590
Sulphur	0.032	0.077
Lime	0.080	0.150
Magnesia	0.011	0.015

Nos. 15a and 15b are the ores mined from the bed on the summit of the Pilot Knob.

No. 15c, soft blue ore.

No. 15d, No. 3 ore taken from the dump.

Nos. 15e and 15f are averages of the ores shipped for six months in 1885.

The Shepherd mountain ore is very high grade.

Shepherd Mountain Ores. The next ore body of the porphyry region from the stand-point of productiveness is Shepherd mountain. It falls far behind, though, either Iron mountain or Pilot Knob in this respect. As regards the purity of its ores, however, it will hardly take a second rank. In physical characteristics the Shepherd mountain ores are more closely allied to the Iron mountain ores than to those of either Pilot Knob or Cedar hill, although the latter are only about one mile distant. The ores of Shepherd mountain are coarsely crystalline, for the most part, and usually highly magnetic.

The following are some partial analyses of the Shepherd mountain ores: —

	(16) Per cent.	(17) Per cent.	(18) Per cent.
Metallic iron	65.39	66.52	64.81
Phosphorus	0.013	0.011	0.017
Phosphorus ratio	0.020	0.016	0.026
Sulphur	0.077		

Sample No. 16 was taken from a stock pile recently mined containing about seven hundred tons. Samples Nos. 17 and 18 were taken respectively from the upper and lower part of the veins.

Cedar Hill Ores. Cedar hill has yielded little or no ore to speak of. A small deposit, occurring very much in the same manner as Pilot Knob ores, was found on the summit of the hill. In many respects the ores here closely resemble the ores of Pilot Knob. Below are two analyses of the ore: —

Cedar hill has yielded but little ore.

	(19) Per cent.	(20) Per cent.
Metallic iron	66.61	65.47
Phosphorus	0.006	0.039
Phosphorus ratio	0.009	0.060

Nos. 19 and 20 are average samples of the vein ore at Cedar Hill.

A sample of ore, taken from Lewis Mountain, yielded —

	(21) Per cent.
Metallic iron	59.22
Phosphorus	0.027
Phosphorus ratio	0.050

Complete Analyses. In addition to the above analyses a few complete analyses of the porphyry ores, taken from Dr. Schmidt's report on the Iron Ores of Missouri,[1] are included here:

[1] Report Geological Survey of Missouri, 1872.

Analyses Iron mountain ore.

	(22) Per cent.	(23) Per cent.
Insoluble siliceous matter	4.71	1.88
Peroxide of iron	91.45	95.04
Protoxide of iron	2.34	2.57
Alumina	0.93	0.75
Lime	0.45	0.15
Magnesia	0.19	0.12
Manganese	0.00	0.00
Sulphur	0.00	0.05
Phosphoric acid	0.252	0.071
	100.322	100.586

These correspond to: —

Metallic iron	65.78	68.53
Phosphorus	0.110	0.031

Nos. 22 and 23 are taken from Iron mountain. No. 22 is a vein ore, while No. 23 is taken from the surface.

It will be noticed here that the vein ore is much higher in phosphorus and inert matter than are the weathered surface ores.

The following complete analyses of the Pilot Knob ores show practically the same results as the partial analyses before given: —

Analyses Pilot Knob ore.

	(24)	(25)
Insoluble siliceous matter	14.75	5.57
Peroxide of iron	84.83	90.87
Protoxide of iron	0.15	1.67
Alumina	0.75	0.53
Lime	0.21	1.76
Magnesia	0.14	0.13
Manganese	0.00	0.00
Sulphur	trace	0.078
Phosphoric acid	0.035	0.069
	100.365	100.677

This gives: —

Metallic iron	59.15	64.91
Phosphorus	0.015	0.031

No. 24 is soft ore from the central portion of the main ore body, while No. 25 is taken from the hard one of the central part of the main ore bed.

A complete analysis of ore from Shepherd mountain gives: —

	(26)	(27)
Insoluble siliceous matter	6.76	15.33
Peroxide of iron	86.56	84.60
Protoxide of iron	2.97	.....
Alumina	1.55	0.32
Lime	0.35	0.38
Magnesia	0.04	0.15
Manganese	0.00	0.00
Copper	trace in 5 grms.	....
Sulphur	0.00	0.021
Phosphoric acid	0.039	0.065
	100.269	100.866

Analysis of Shepherd mountain ore.

The above analyses correspond to: —

Metallic iron	64.31	59.22
Phosphorus	0.017	0.027

No. 27 was taken from Lewis mountain near Arcadia. The excess over 100 is due largely to the presence of iron protoxide which was not determined.

A specimen of ore collected by Prof. Pumpelly from Buford mountain gives the following results: —

	(28)
Insoluble matter	8.54
Peroxide of iron	68.30
Peroxide of manganese	19.46
Sulphur	0.011
Phosphoric acid	0.102
	96.415

Analysis of Buford mountain ore.

This ore bears, in places, distinct traces of stratification. The ore of Buford mountain is limited in quantity, is soft, inclined to earthy and is dull in color. The deficiency in the total of the analysis is probably due to lime and carbonic acid which is not determined.

From the analyses given it will be seen that the porphyry iron ores are, as a rule, very rich in iron, low in phosphoric acid and sulphur and other deleterious elements, while the high percentages of metallic iron show the low percentages of inert siliceous or aluminous matter. The ores are available for the highest metallurgical uses and are widely sought for by manufacturers of

The porphyry iron ores are Bessemer, as a rule.

Bessemer steel. Even with the dull iron markets of to-day, there is a ready sale for the ores of Iron mountain and the same could be said of Pilot Knob while it was a producer.

Surface prospecting has failed to reveal other deposits.

The desirable qualities of these ores have caused extensive prospecting on the surface and it is with regret that it is here recorded that this prospecting has thus far been without success. The localities which apparently promised well in 1872 have been tried and found wanting. None of them have realized the hopes of the prospectors. It is to be hoped, however, that the methods of prospecting with a diamond drill may yet reveal deposits of these valuable ores, now hidden from the eye which seeks for them on the surface alone.

THE ORIGIN OF THE IRON ORES.

It has been suggested that iron veins are eruptive.

Mode of Accumulation. Igneous rocks often occur injected as dikes of various sizes in more recent rocks. Many have suggested that metalliferous veins were formed in the same manner. Rogers, in his report on the Geology of New Jersey, 1836 to 1840, held that the bodies of magnetic iron so abundant in the Archæan gneisses of New Jersey were thus formed. In the white limestone of the same State are extensive deposits of zinc oxides and silicates. Rogers held that these also were injected igneous dikes and cited the well-known facts that the limestones were whiter and more crystalline in the vicinity of these dikes, and that the heat from these dikes was the cause of this change. This view, however, never obtained wide acceptance, but, even had this been the case, there are facts that would prevent its adoption to explain the veins of iron found in the porphyry rocks of Missouri. Iron oxide is only fusible at a very high temperature. Even at a comparatively low temperature oxide of iron, when brought into contact with silica or silicates, tends to unite with them and form a different compound. This has evidently not been the case in this region, for the line of contact between the porphyry rock and the veins which intersect it is very sharp even in the smallest veins. It will thus be seen that this iron could not have been injected in a molten state. In many volcanic rocks fissures are often filled by metalliferous and other minerals which have been volatilized by the heat of

the molten rock. Such veins are usually mixtures of many minerals, very few being filled exclusively with ore. Experience has also taught us that such veins are limited in size. Veins filled in this way would also be apt to reach very great depths undiminished in size. Though the veins of ore are limited to a very small area of the porphyry rocks, there is no good reason why, if they are veins of distillation, they should not be found co-extensive with the porphyry. Further, a strong argument against the origin of these veins by distillation is the presence of quartz crystals inclosing scales of hematite and also having numerous cavities filled with a liquid.

They cannot be veins of distillation.

The thought that these veins may have been sedimentary deposits and cotemporaneous with the rocks which inclose them may be dismissed without consideration. The great irregularities of the veins both as to size and distribution, even if there were no question as to the origin of the enclosing rock would exclude this explanation.

Nor of sedimentary origin for the most part.

Veins of segregation do not usually have as sharp an outline as do the veins of these porphyries. They are also very regular in shape as a general thing. As found in stratified rocks, they usually follow the lines of stratification. If the rocks are jointed the veins are usually largest at the intersection of the joint planes, from which intersection they reach out along the planes of diminished size. The conclusion arrived at from the study of the veins in the porphyries is that they are veins of infiltration. Infiltration and segregation are not very far apart. In segregated veins, however, there is no necessity for supposing that there is an initial crevice or fissure. Some cause or other may determine a flow of percolating waters to a certain part of the rock, and when the waters become sufficiently saturated replacement and precipitation take place. When once this action begins it does not cease until the waters are wholly free from the mineral in question. In the case of infiltration, an existing crevice or fissure in the rock is presupposed. Along this crevice waters charged with mineral in solution are carried, and by precipitation the crevice is gradually filled. The bounding rock walls in this case are not usually impregnated with the mineral. This rarely takes place even if the circulating waters find their

Segregation does not satisfy the conditions.

Infiltration the most probable explanation.

way to the crevice through the country rock. Veins of infiltration probably differ more from those of segregation in their appearance after they are formed than they do in the manner of their formation. The same may be said of impregnated veins. In all cases the work is done by waters of varying degrees of temperature and purity.

Water, under certain circumstances, is one of the most powerful solvents known. Let us see what conditions would be necessary in order that the iron of the porphyry district might be put into solution and finally precipitated in the crevices of the porphyry rocks. Rocks, however dense, are to some extent permeable by water. The finer grained the rock the farther, by capillary action alone, would the water penetrate. The fact of

Solvent water circulates to a greater or less extent through the densest rocks.

the permeability of rocks by water may be easily demonstrated by taking a piece of sandstone and heating it below red heat for a long time. This will drive out the last trace of hygroscopic water. If then the sandstone be weighed, then immersed in water, brought out and dried, then weighed again, it will be found that it has increased noticeably in weight. This increase is due entirely to absorbed water. In many cases five to twenty-five per cent. of water will thus be absorbed. In the case of milky white marbles, immersion in water will make them translucent and they will also increase in weight. In addition to the force of capillary attraction, in large rock masses, hydrostatic pressure will tend not only to force water into minute fissures, but into the body of the rock itself. If, in addition to capillary attraction and hydrostatic pressure, the rock be of different temperature in different places, and this will certainly be the case, a difference in density of the water as the result of difference in temperature, will also induce a circulation of the water in the rock. Difference in density due to matter held in solution will also tend to the same end. So in addition to the increase of absorption one must consider the fact that this absorbed water is in a state of perpetual motion as well.

The temperature of the water will depend upon the temperature of the air, the temperature of the rocks themselves, and also upon the amount of chemical activity in the rock mass as a whole. It is a well known fact that hea'

more powerful solvent action than it has when cold. Even pure water when heated to a moderately high temperature attacks almost all known substances. It may well be imagined then that if no dissolved substance were present in the rock water, as absorbed water is called, it would exert a very powerful action on rocks and minerals which contained it. Water, however, is very seldom pure. While on the surface of the ground, or even in the air in the form of vapor, it absorbs gases from the air such as carbonic acid, ammonia, etc., and from the soil it would take various alkaline substances and organic acids. These alone, without an increase of temperature, would enable the water to act powerfully on rocks and minerals, but, with the addition of a very small amount of heat, the action is greatly increased in power. The decomposition of iron bearing minerals will then take place and the iron will be carried off in solution.

Solvent power of waters is increased by heat and absorbed gases.

As to the formation of crevices in the rocks many causes may contribute to this end. The changing of anhydrous minerals to a hydrated state will swell the rocks and a consequent cracking and fissuring will take place. Along these fissures the water will find its way, constantly enlarging them. Side by side with this destructive action is going on what may be called a reconstructive action. The rock water circulating through the mass and along the veins and fissures, is continually reaching the point of saturation, the point where deposition must take place whenever a favorable opportunity occurs. Oxidation on coming into a cavity or fissure, or a change of temperature, due to the same cause, will often determine this. Then the mineral which is the most readily precipitated, and this is usually the one which is the most difficultly soluble, will be precipitated at once. Thus a vein may be filled with one mineral to the almost utter exclusion of another. For, as it is true that different minerals do not pass into solution with equal readiness, it is also true that they are not precipitated at the same moment, since a cause that might be sufficient to precipitate one mineral might not be equal to cause the precipitation of another. It thus happens oftentimes that in a vein several minerals may be precipitated and each one will be sharply separated from the other.

Though the circulating waters act destructively they simply change minerals from unstable to more stable forms.

We have thus far confined our attention to rocks in general

although we have had more especially in mind the formation of veins in massive rocks. Let us see how percolating chalybeate waters would operate in stratified or sedimentary rocks. An example can be taken more readily from rocks which are more widely distributed in the limestone and sandstone of the State. Let us suppose a section somewhat as follows: —

	Feet.
1. Sandstone	4
2. Limestone, gritty, passing into 3	4
3. Limestone, pure	6
4. Sandstone	1
5. Limestone with calcareous shale	2
6. Sandstone, massive	20

Solvent waters select the less refractory rocks, and replace the parts removed by iron.

In stratum 1 percolating waters would have no effect. Stratum 2 would have its lime entirely removed. If the percolating water carried iron, the lime might be replaced by this mineral. Stratum 3 consisting of pure limestone, might similarly be entirely removed and entirely replaced by iron ore. Stratum 4 would be untouched. No. 5 would have the calcareous matter removed and replaced by iron while the shale would be untouched. No. 6 would also be untouched. In other words, the entire soluble constituents of the rock might be removed and replaced by oxide of iron precipitated from the solvent water. This section, thus acted upon, would become as follows: —

	Feet.
1. Hanging wall of sandstone	4
2. Siliceous lean ore	4
3. Solid bed of good ore	6
4. Siliceous rock band	1
5. Bands of alternating rich ore with lean slaty ore	2
6. Footwall of sandstone	20

While this description is not taken from an actual occurrence it will illustrate exactly what may occur when circulating waters act on stratified rocks.[1] As in the case of the massive rocks these waters remove the more soluble portions of the rock. If the rock is wholly soluble a bed of rich iron ore is left and lean

[1] An actual occurrence under conditions very similar to the one described above is given by Prof. J. P. Lesley, Vol. I, Summary, Final Report, Geo. Sur. Penn. 1892, p. 351.

beds, or beds of rock are left, according to the solubility of the stratum. There has been occasion to refer to this more definitely when describing the bedded deposits of conglomerate and of specular ore on Pilot Knob. It can further be imagined that, for many reasons, removal of any rock stratum by solution might cease abruptly, and the deposition of iron cease as suddenly also. We would then have a case which often occurs in actual mining operations of an ore body suddenly "heading out;" or the ore body may gradually grow lean by imperfect solution and replacement until it reached a point where it is no longer profitable to work the deposit. In this case, as the miners express it, the ore "leans out."

This action of removal and replacement often ceases abruptly.

Of the two kinds of deposits mentioned above, the vein and bedded deposits, veins are, with rare exceptions, much more unsatisfactory to the miner then are beds, whether the latter were deposited contemporaneously with the rocks or were secondary in origin as described above. Veins more often vary from lean to rich or they "pinch" and "swell" in a very inconvenient manner. Even the largest often break up suddenly into "strings" (thin veins which lead off from the main body), or even disappear altogether.

In connection with the consideration of the veins found in the porphyry rocks it is interesting, not to say profitable, to inquire into the immediate source of the iron ore which fills them. As has been before mentioned both the granites and porphyries of this region contain a large per cent. of iron in the form of crystalline scales of hematite and grains of magnetite. Although, when we think of the enormous masses of solid iron ore in the veins and conglomerate beds of Iron mountain and other places, the amount of iron disseminated in the rocks seems insignificant and wholly inadequate to supply these great deposits, yet we must remember the proportion which the enormous masses of porphyry bear to the bodies of iron ore. The masses of porphyry which are now comparatively fresh have not, of course, been robbed of their iron to fill these veins; but, if we take the fresh porphyry as a fair index of that which has long since been decomposed and carried away, we may obtain some basis, however slight, to which our thoughts may turn.

The source of the iron in the veins was probably the iron scattered through the mass of porphyry now removed by denuding agents.

We can picture to ourselves the great hills and mountains of porphyry which must have existed before atmospheric agencies began the work of destruction, and, having done this the disparity between the source of the vein matter and the size of the veins will not seem so great. The residuary masses of clay from the decomposed porphyry is still very great, but this can be only a small fraction of what has been. Prof. Pumpelly[1] speaks of this as follows: "Both the Archæan crystalline rocks and the Cambrian strata have undergone immense changes in volume and in other respects, under this long continued influence" (atmospheric agency). "The gradual removal of the soluble constituents has left important residuary deposits of such substances as were insoluble. The more conspicuous instances of this kind among the pre-Cambrian rocks are residuary occurrences of iron ore. The constituents of the granitic and porphyry rocks offered a far greater resistance to the action of this process of removal that those of the limestone strata. Still the amount of disintegration and of full decomposition has been very great in these older formations, although it would not be easy to say what proportion of this has taken place since the deposition of the Cambrian limestones. The granites and porphyries had undergone an enormous erosion before the limestones were formed; an amount at least several times as great as that they have suffered since that remote time."

Residuary occurrences of clays, iron ores, etc., testify to great shrinkage in volume.

It will be seen that Prof. Pumpelly believed in a period of great erosion before the rocks were covered by the sediments of the Cambrian seas. In porphyry outcrops, sheltered from corrasion by rains, the rock mass is often decomposed to depths of fifty feet or even more. Through this decomposed rock waters charged with organic matter are constantly percolating and this re-appears in the form of springs at a lower level. The reddish slime which the spring deposits on exposure to the air shows the nature of its work. We can imagine that the water emerging in the form of a spring is not the total amount that has percolated through the clay debris. Part of it finds its way into the rocks below and coming into contact with limestone

Circulating waters charged with organic matter leach these clays of their iron.

[1] Report Geological Survey of Missouri, 1872, Part I, p. 9.

drops its burden of iron and takes the limestone instead. In a similar manner, in the long ages before Cambrian times, we can imagine that these great ore veins were filled; but in this case the rock removed by solution would be the porphyry itself.[1]

Topographic Changes Involved. We find, in our study of the large veins, that they are imbedded in a more or less decomposed porphyry. We also know that these veins have at one time stood much higher than at present and that they were supported by porphyry rocks. There will be no objection to admitting that such veins are secondary in origin, that is that they are younger than the rocks in which they are found. Let us, starting from this point, try to picture their history.

The topography is not the same to-day as in former geological times.

In the first place, whatever the origin of the porphyries, it is allowable to imagine the porphyry region to have been in pre-Cambrian times, mountainous, or at least hilly. These hills and valleys must have had cracks or fissures in the rocks as we find them to-day. Naturally, erosion or weathering and denuding agencies would begin at the highest points. The products of disintegration would wash from the higher to the lower points. Iron dissolved from the decomposed rocks would, by means of percolating waters, find its way to the fissures in the unweathered rocks at a lower point. In these fissures it would be precipitated, either chemically by coming into contact with alkaline or other reagents, or would, by slow absorption of oxygen, be made insoluble. This, in time, would fill the crevices and fissures in the lower rocks with a substance much less susceptible to weathering influences. The rock mass, thus cemented, would, as a whole, also tend to resist weathering more effectually than the rock not thus protected. Iron deposits filling fissures would not be formed at the highest points since solution would tend to carry it either deeper into the hills or into the valleys below. The result of this would inevitably be that the erosive agencies would be much more effective on the elevated portions of the

Erosion naturally begins at the highest point and would be more rapid there than in] the valleys.

[1] See the iron ores of the Marquette District of Michigan. Amer. Journal of Science III, Vol. XLIII, pp. 116–132, by Prof. C. R. Van Hise, for a history of solution and redeposition. Also Origin of the Ferruginous Schists and Iron Ores of the Lake Superior Region. By R. D. Irving, same journal, III, XXXII, pp. 255–272.

This would result in the hills and valleys changing places.

country than were the lower. Gradually the hills would tend to reach the valley level; the valley country being protected by iron dikes and veins, would resist such erosion. The final result would be that, in many cases, the hills would be changed to valleys, and the valleys to hills.

This process operates in greatly folded regions.

This process takes place in countries where the rocks are forced into synclines and anticlines, or A-shaped hills and V-shaped valleys. In this case the rocks would be more broken at the crests of the anticlines, or A-shaped hills, than in the synclinal valleys. Instances of this will be found in almost any work on geology. The broken rocks of the anticline present more surface to weathering, and these go to pieces more readily. The principle is the same in either case, *i. e.*, varying degrees of susceptibility to denuding agencies.

The two following Figs., 25 and 26, show the relative positions of the hills and valleys in the extreme phases of weathering as described above.

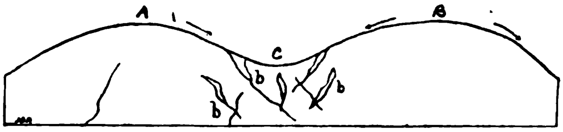

FIG. 25. Profile of Archæan topography prior to erosion.

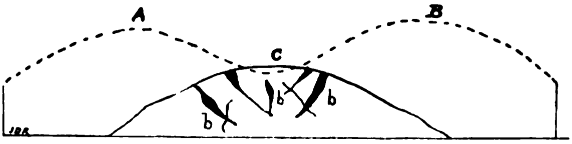

FIG. 26. Profile of Archæan topography after erosion.

In Fig. 25 we will suppose the Archæan landscape to be as depicted, the arrows show the course of percolating waters, and b. b., the location of large fissures and veins which are being filled with iron. Fig. 26 shows the other extreme, where the hills have given place to valleys and *vice versa*, the dotted lines indicating the positions of the former hills.

If now we carry this process farther we can picture the history

of any one of these hills, such, for instance, as Iron mountain.

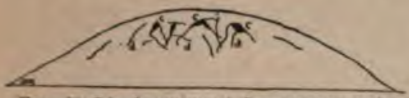

FIG. 27. Ideal section of Iron mountain before erosion exposed the veins.

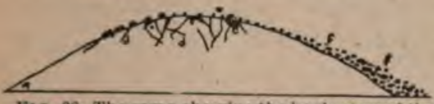

FIG. 28. The same showing the beginning of the formation of boulder ore.

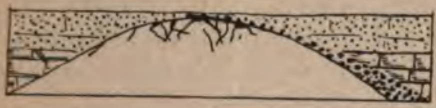

FIG. 29. The same after boulder ore is buried under Cambrian strata.

Fig. 27 shows such an isolated hill. In this case c, c, will represent the larger veins and d, d, the smaller, commercially unimportant, veins. Fig. 28 shows the same hill when the process of denudation has proceeded to such an extent that the more susceptible rock supports have weathered away. The result of this is that the veins break up into fragments, e, e, and lie more or less thickly scattered in the clay or are gathered into beds of conglomerate, f, f. We will suppose this process to be carried well on towards Cambrian time. Fig. 29 shows the point where the earth crust movement has lowered the porphyry and its ore veins and fragments below the Cambrian waters. The result has been the covering of the iron boulders beneath the mantle of Cambrian rocks. This is as far as we need to pursue this particular phase of the subject.

The veins give rise to boulder deposits, later buried beneath Cambrian rocks.

In the single example cited not every possible condition can be reviewed, but there are points which it may be well to give further consideration. We can not imagine that the porphyry hills of the Archæan age were of uniform height, nor that the valleys reached to a uniform depth. There may have been, and probably were, iron deposits high up on the slopes of hills, or in valleys high above the general level, but yet low enough to be the centers of large drainage areas. These rocks, having their cracks and fissures filled and cemented with iron to a great depth, would naturally present a greater resistance to erosion than the rocks free from veins, as in the case already considered. The future of such deposits would, in the end, vary from that now represented at Iron mountain. As the enclosing and surrounding rocks were worn away, the ore veins would, as in the case of Iron mountain, be attacked and comglomerate beds would be

Deposits doubtless originally formed at higher altitudes.

formed on the secondary slopes and valleys. By continual erosion these beds of conglomerate would be moved farther and farther down the slopes and valleys. Carrying this process to its legitimate conclusion we can imagine that, in the end, the veins which had so long protected the hill would at length be almost wholly destroyed or at most only traces of them would be left. The diminishing veins would furnish less material for conglomerate deposits and the former material would be carried away faster than the new material could be supplied. The end of such a process, as we see it at the present time, would be mountains or hills with veins of varying size, the remnants of once greater deposits. The slopes of the hill would be covered by only scattering fragments or isolated boulders from a once more extensive deposit. Localities such as Shepherd and Clark mountains and Cedar hills are examples in point. It can not be positively asserted that such has been the history of their deposits, but it is probable that such has been.

Of such deposits less would be expected to remain to-day.

The points which we have thus far discussed are as follows: First, the effects of erosion in changing hills to valleys and valleys to hills; second, the effect of erosion in a valley of moderate elevation in developing a mountain like Iron mountain; third, the effect of erosion in producing from the iron cemented rock of a valley of greater elevation, mountains like Shepherd and Clark mountains and Cedar hill. In the cases above considered erosion has, owing to greater original elevation, almost entirely removed the original iron deposits in Shepherd and Clark mountains and Cedar hill, while Iron mountain, being at a less elevation, its deposit was only partly disturbed.

Erosion ultimately tends to the entire removal of vein deposits.

There is a third case which may with profit be considered. In the first two cases, we presuppose an accumulation of ore in fissures of rocks made under more or less elevated valleys. Let us now suppose a case where deposition took place still lower in an original valley than in either of the above cases. Here, before erosion had proceeded far enough to raise the hill prominently and to cause denuding action to naturally affect the vein deposits, we can imagine the depression of the earth's crust to have gone on to such an extent that the waters of the Cambrian seas began the work of covering the lan' '*, thus

Vein deposits may have been buried by Cambrian sediments.

ending the period of subærial accumulation. In a case of this kind, even if the deposit of iron in the rocks be very extensive, no sign of its presence would be found on the surface.

Formation of the Pilot Knob Beds. In regard to the origin of this somewhat unique ore formation of the Pilot Knob, the opinion has been expressed that it is sedimentary.[1] It is hardly fair to let this statement pass unqualified. Prof. E. Haworth, who has had charge of the study of crystalline rocks, has shown that many of the porphyry rocks are eruptive, and that the gangue matter of the conglomerates and many of the massive rocks are devitrified volcanic glasses. The conglomerate pebbles or breccia fragments, he points out, are also devitrified glasses, and these fragments he further shows are themselves made up of brecciated fragments. From these facts he infers that the hitherto supposed sedimentary beds of Pilot Knob are, in reality, but pseudo-beds caused by the flowing of viscid lavas. His explanation of the conglomeratic structure is that, as the lavas flowed down the sides of the mountain, they became cooled on the surface. The more liquid lavas underneath still continued to move, however, the congealed crust under this strain broke up into fragments and these fragments were engulfed in the molten mass beneath. Or, successive flows over the former brecciated crust of a still older flow engulfed these fragments thus forming apparent beds of breccia. The unsolidified lava beneath growing more and more viscid, gradually drew out into finer and finer bands until no longer able to move. Subsequently, percolating waters removed the more soluble portions of the lava and replaced them by iron.[2]

The conglomerates and breccias of Pilot Knob are devitrified glasses.

The breccias were caused by cooling of lava crusts and by successive flows.

There seem to be very grave difficulties in the way of this explanation. To satisfy the above conditions, there must have been a volcanic peak much higher than Pilot Knob. This peak must have been to the north or west of Pilot Knob, since the flow is towards the south. In this case, the whole, or at least the greater part of the cone or peak, consisting of harder rock,

There are serious objections to the above theories.

[1] Prof. R. Pumpelly, Report Geological Survey of Missouri, 1872, p. 26.

[2] For a fuller statement see Bulletin No. 5, Geological Survey of Missouri, 1891. The Age and Origin of the Crystalline Rocks of Missouri, by Erasmus Haworth.

has disappeared, while the more easily destructible volcanic cinders and broken lava forming a part of the slope of the mountain have entirely disappeared. It would also be supposed that the coarse and fine breccia would be indiscriminately mingled throughout the whole mass of the conglomerate if it were a lava breccia, whereas actually the coarser conglomerates are at the summit of the Knob, and the breccia with fragments still remaining just as distinct and even more numerous, is much finer and the slaty structure is correspondingly fine at the bottom near the ore body. This fine conglomerate, all the while sharply brecciated, gradually passes into an aphanitic slate. In the case of a brecciated formation, such as Prof. Haworth describes, one would expect that, on the surface where the cooling was comparatively perfect, the angles of the fragments would be very sharp, and that this angularity, as the temperature of lava increased towards the center, would diminish and the fragments present a drawn appearance. The reverse of this is decidedly the case. The angularity is retained until the last trace of the breccia has disappeared. Also, in the slaty rocks, there ought to be a trace of the knots and even of the porphyritic crystals. The slates, however, present no such appearance, and split in the even smooth planes of the typical argillite.

Brecciated fragments are as angular at the center of the bed as on the surface.

The jointed structure in the conglomerates has already been referred to. If it be allowed that the beds of Pilot Knob are of sedimentary origin there is nothing incompatible in the idea that the material of such sediments was originally of eruptive origin. The replacement of the sediments by iron ore is, to say the least, as easily accomplished as in the case of eruptive rocks.

No objection to considering the sediments as derived from an eruptive rock.

If the Pilot Knob ore is of sedimentary origin, the questions arise, are there no other deposits of similar origin, and why are not others to be seen?

The answers to these apparently simple questions are exceedingly complex. To answer them recourse must be had to a consideration of the conditions under which the ores were probably formed. Calling to mind the conceptions of the pre-Cambrian topography described under the discussion of the origin of the ore deposits of Iron mountain and others similar to them, we

Other sedimentary deposits similar to Pilot Knob have probably existed if they do not exist now.

conceived that the porphyry region in those times must have been a diversified landscape of hills and valleys of varying altitudes. We can further imagine that many of these valleys may have been lake basins or they even may have been open to the inroads of the Archæan seas. These lakes were fed, as lakes are now, by streams bearing sediments and minerals in solution, and also streams must have entered the seas. We may even imagine that the porpyhry region represented the higher portions of the Archæan continent and that from a perhaps distant sea coast arms of water extended into the region of the porphyry hills. The inevitable consequences of such waters must have been the formation of sedimentary beds and these beds would of necessity be composed principally of porphyry and granite detritus. If limestone formed at all it must have been sparingly formed in the long estuaries where the water was comparatively shallow and in the long lapse of time the greater part of it would be destroyed, unless step by step with its destruction and removal some more refractory substance took its place. In this case the limestone itself would not have been preserved, simply its place and form would be reproduced.

As in the case of Iron mountain, let us try to picture the history of Pilot Knob. The following cuts will show the successive steps through which it is not at all difficult to imagine that Pilot Knob may have passed.

Iron bearing rocks of the valleys converted by erosion into hills.

In Fig. 30 we have the first steps of degradation. Sedimentary ore is forming beneath the waters at 4, and, higher up, at 7, a lake has arranged the detritus brought down from the hills surrounding it. Veins have also been filled at 2. With a movement of continental elevation going on the period of deposition will gradually grow less and less until, finally, deposition will cease at 4. When 4 is at length raised above the construction period the work of destruction will begin. The valleys grow deeper and deeper while the former valleys filled with stratified sediments, as at 6 and 7, and with iron veins at 2, protected in some cases by included deposits of iron, will, by the degradation of the surrounding rocks, rise gradually higher above the new level. With the destructive action the more soluble strata in 4 will be etched away and iron will replace them.

The next stage will be that of Fig. 31, where the now hardened sediments at 4 will resist erosion and the former water bed will itself be lifted up as a hill brought into relief by erosion of the surrounding porphyry.

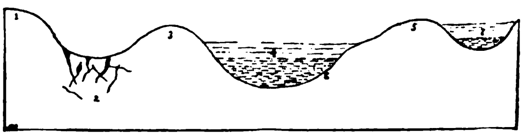

FIG. 30. Ideal section of topography in Archæan time.

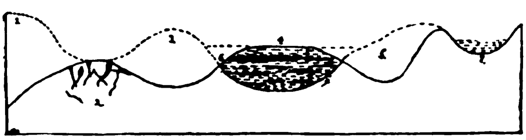

FIG. 31. The same after deposition of iron ores and after erosion.

FIG. 32. The same showing growth of boulder ore beds.

Fig. 32 represents a period when the former lake bed, at 7, has been entirely swept away. During this period the stratified deposit, at 1, has been undermined and the detritus has been scattered along the slope of the hill or rolled down to the valley below.

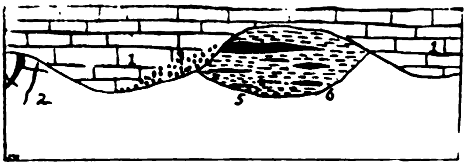

FIG. 33. Ideal section of Pilot Knob covered by Cambrian limestone.

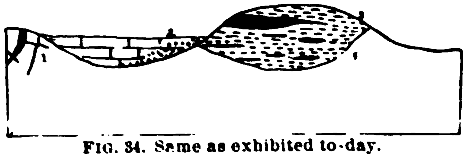

FIG. 34. Same as exhibited to-day.

Fig. 33 shows the entire series covered by a mantle of Cambrian rocks. This period, of course, represents a time when erosion has ceased, a period when the sinking of the Archæan continent gave full sway to the Cambrian seas.

Fig. 34, the last one in the series, represents a period of time which, practically extends to the present. Here, by the elevation of a continental area, the work of the Cambrian seas is being undone. The more easily eroded sedimentary rocks are being swept away more rapidly than the more refractory porphyry, and gradually, with the sweeping away of these rocks we are looking upon an Archæan landscape preserved, almost unaltered since the beginning of the Cambrian age.

Limitations of Theory Advanced. It is by no means presumed that the outlines of the possible, not to say probable, geological history or earth sculpture in the Archæan period of the porphyry region is accurate in detail. In fact few details are given. It is safe to say that no period of history can be exactly reproduced ages after it has been enacted. There are innumerable departures or exceptions possible, which is equivalent to saying that there are many causes that will contribute to the same end. From our general knowledge of geological forces as we see them operating to-day, there can be little doubt but that the main features outlined above are possible not to say probable. We can, then, accept the above history as approximately true, and base our conclusions upon them.

The foregoing theory is probably true in general.

Bearings of Theory upon Future Developments. We learn from the prospecting done under the direction of Prof. Potter, at Iron mountain, that there are no other great veins of ore corresponding to the veins exposed at the summit of the mountain. Numerous drill holes have been put down to a depth of over 200 feet. The ground has been carefully mapped out and the drill holes have been located in such a manner that, had large deposits in veins existed, their presence must have been shown by the cores. These holes have been put down in the porphyry. Drill holes have been put down with the same care at Pilot Knob and near Shepherd mountain. These also have failed to show the existence of workable veins of ore.

Prospecting with diamond drills seems to confirm the theory given.

A shaft put down at Iron mountain has shown the existence of a large deposit of conglomerate ore under a mantle of Cambrian rocks. This deposit is extensive and valuable but gave no sign of its actual existence on the surface. A series of drill holes put down at Pilot Knob, through the Cambrian rocks, has reached a large deposit of boulder ore similar, in many respects, to that at Iron mountain. Drill holes have intersected veins in the porphyry at Iron mountain and also near Shepherd mountain, but these have been of small size and of no commercial value.

Boulder deposits under the Cambrian rocks at Iron mountain and Pilot Knob.

It is a matter of surprise to a thoughtful man that of all the great porphyry area in Missouri, covering an area of between three and four hundred square miles, there are less than

twelve square miles in which iron ore has been found, while the area in which workable deposits have been found could easily be limited to much less. This is contrary to experience generally. In the range of mountains reaching from central Pennsylvania through northern New Jersey and southwestern New York there are large deposits of magnetic iron ore. These deposits are distributed throughout the entire length of the major axis of this range. In New Jersey alone there have been at least 325 openings made in an area covering less than 700 square miles. There were, in 1890, 32 of these in active operation. The area in New York State is much less and there are proportionally fewer mines, but there are, nevertheless, many known deposits. The same may be said of Pennsylvania. It will only be sufficient to mention the Lake Superior region to recall that the same is true there also. This persistent association of a given mineral with a certain rock is by no means confined to iron ores, but is true of mineral deposits generally. It is all the more surprising, therefore, to find such an exception in the region of the porphyry rocks of Missouri. In the light of the facts given in regard to the deposits at Iron mountain, Pilot Knob and other minor deposits, it may be well to inquire if there is no reasonable way of accounting for this apparently striking exception than simply to say that there are no other deposits than the ones mentioned above. The specular ores in this region are all of undoubted secondary origin. Even the bedded deposits must have been secondary to the vein deposits if contemporaneous with the beds of rock. If the outline of the history of the origin of the porphyry ores as given is at all in accord with the actual history, there is no good reason for supposing that the deposits already known *are* the only ones which may exist. If, in Fig. 34, the porphyry hill at 3, capped as it is by sedimentary rocks and ores, had been eroded to the point of the entire destruction of these beds, we can very easily imagine them to have been reduced to a conglomerate form and to have been covered by Cambrian sediments to such a depth that subsequent erosion would fail to expose them. Again, we can imagine that beds may have been formed at a lower level than the original bed referred to, which may never have been

Metalliferous deposits generally coextensive with the rocks in which they occur.

The porphyry ores seem to be an exception to this rule.

disturbed at all. Still further, as in the case of the assumed lake deposit, Fig. 32, we can imagine a case where all traces of a former deposit of sedimentary rocks had been swept entirely away. If the Archæan topography is in a general way as we have pictured it, the conclusions which have been drawn from that assumption must certainly hold. Still further conclusions may be drawn; with the wearing down of hills containing iron deposits, the iron ores would have been carried lower and lower and would finally find a resting-place in the lowest valleys. This degradation may have proceeded to such an extent that no trace of the former veins would exist in the hills where once they were. If this holds true, or is even plausible, there is yet a wide field for prospecting in the porphyry region. The deposits of conglomerate ores, if they exist, must lie beneath the later sediments of Cambrian age. Already several deposits under the above conditions have been found. These have been, however, closely connected with the great ore deposits which have plainly appeared on the surface. Between nearly all of the porphyry hills there are valleys filled with Cambrian sediments. These are comparatively limited in extent and are comparatively shallow as to depth. The rocks consist of limestone and sandstone and are almost wholly free from chert. Boring with a diamond drill in these places can thus be done under the most auspicious circumstances. Many of the localities are readily accessible to a railroad or could be connected with one at slight expense.

How deposits of iron could have been formed and made no surface show.

The difficulty of locating such deposits would be far greater than with any other deposit thus far mentioned. The only recourse would be the diamond drill or shaft sinking.

The validity of the conclusions to be drawn from the above discussion is not likely to be tested soon from a commercial stand-point. The present state of the iron market, the fact of more accessible iron ore fields, and other apparent reasons prohibit the practical test of such conclusions; but a close observer cannot fail to note the striking fact that the greatest porphyry ore deposit, Iron mountain, is on a point very much lower than the surrounding porphyry hills, and that such erosion as has taken

Erosive agents have concentrated otherwise unworkable ores.

place has done little more than to concentrate the ores and make them more accessible and cheaply mined. Deposits, of which Shepherd mountain may be taken as a type, are in remnants of hills high above the surrounding country. If we regard the bedded ore deposits of Pilot Knob as of sedimentary origin, and one can hardly doubt but that they are, the underlying contact line of solid porphyry which includes this bed must be taken as the level of a one time valley or depression among porphyry hills. Below the level of this line the level of now existing valleys must be regarded as the work of erosion.

ents of ore all veins be signs of d detrital sits.

Prospecting for deep untouched or unweathered vein deposits, therefore, becomes rather unattractive and unpromising. If they exist they lie more or less deeply buried under Cambrian sediments of varying depths. Prospecting for fragmentary ore made up from weathered surface beds promises much greater results. In such cases, in the place of having no exterior guides, we have either remnants of veins, such as are exposed on Shepherd mountain, or scattered fragments in the clays like those at Clark mountain and on the hill west of Iron mountain. As has been pointed out, the destruction of vein deposits gives rise to beds of conglomerate and the hematite boulders of the conglomerate being more indestructible than the porphyry, will move farther and farther down as erosion progresses. If, for instance, pre-Cambrian erosion had gone but little farther, the Iron mountain deposits would have been hidden completely from sight beneath the rocks which now flank the mountain. The most hopeful place then for further prospecting will be beneath the limestones and sandstones that flank mountains and hills, upon which are already traces, or even more, of specular iron.

SUMMARY.

To sum up briefly the salient features of this chapter, the following facts can be stated from the stand-point of the geologist. There is little hope of finding new and large veins of ore in the solid porphyry hills. Diamond drilling has shown that no

other large veins exist in the solid porphyry hills in the vicinity of Iron mountain and Pilot Knob. If other deposits exist they are beneath the Silurian rocks in the porphyry valleys. It is quite probable that such deposits exist. Before permanently abandoning this hitherto rich field of iron ore it is well worth while to spend considerable time and money in testing this question on the lines laid out above.

Good reasons for believing detrital, or even vein deposits may exist in the valleys.

CHAPTER IV.

THE RED HEMATITES OF MISSOURI.

HENRY COUNTY — MONROE COUNTY — LINCOLN COUNTY — CALLAWAY COUNTY — COOPER COUNTY — SALINE COUNTY — BENTON, HENRY AND ST. CLAIR COUNTIES — CONCLUSIONS.

The red hematites of Missouri have a fixed geological horizon.

The specular iron ores and other ores, subsequently to be considered, have, so far as we know, no fixed geological horizon. That is, the iron does not form an integral part of the geological horizon in which they are found; but they are essentially secondary in their origin. To this general rule for the iron ores of Missouri the red hematites form, however, a striking exception. They form distinct beds in the Coal Measures and Lower Carboniferous rocks and their age is thus definitely fixed. Unfortunately they seem to be of limited extent and not at all co-extensive with the formations in which they occur.

HENRY COUNTY.

In the Coal Measure sandstone in the vicinity of Brownington and Calhoun, in Henry county, red hematites occur as lenticular masses which grade, by easy steps, into the sandstones in which they are found. Here they are usually highly siliceous on account of the grains of sand which are scattered through the ore. These deposits are not of themselves extensive though they are rather numerous.

In Prof. Broadhead's report on the "Geology of Northwestern Missouri"[1] he says: "At Laban Parks, one and one-half miles north of Calhoun, the upper series of the Calhoun rocks contains

[1] Report Geological Survey of Missouri, 1872. Part second, p. 23.

a good red hematite in considerable quantities. A vertical section of the rocks here would exhibit:

No. 1. Soil.
" 2. Deposit of porous red hematite, about three feet. Good iron ore.
" 3. Three feet brown ocher concretions.
" 4. Twenty-four feet sandstone, upper portion drab and buff ripple marked; brown towards bottom.
" 5. Eleven feet bluish drab and shaly sandstone.
" 6. Dark streak of apparently rotten coal, — No. 5 of Calhoun section."

The iron ores in Henry county seem to be limited in extent and are siliceous.

Similar iron ore is said to occur at several other localities in the neighborhood of Calhoun.

It is thus evident that this deposit occurs in the Coal Measures. Several other localities of a similar nature were visited by the writer and his observations coincided with the above, save that the iron ore generally appeared to be too siliceous to be of much use even if abundant. In case, however, of the deposits being of greater size, the chances would be favorable to greater purity and, hence, commercial value.

MONROE COUNTY.

Although not found in regular beds there are many localities where a beautiful kidney ore is found quite thickly strewn over the surface of the ground, especially when it has been exposed to the action of rains and small streams. Near Paris, in Monroe county, the writer observed numerous boulders of varying size near the bed of a small stream. Those pieces weighed from a few ounces up to one hundred pounds or more. They appeared to be scattered through a red clayey soil. Very likely these are the remains of a more or less extensive bed consisting of earthy ore and loose lenses or "kidneys" of hard red ore of fine quality. The small and earthy ore has probably been washed away leaving the harder lumps scattered through the soil. In this locality there is nothing that would warrant the assertion of the existence of workable beds of red hematite, or, in fact, of any other kinds of iron ore. Yet in nearly every Coal Measure formation known, there are beds of iron ore of greater or less extent, and workable

Scattered kidneys of red hematite ore found, the probable remnants of former beds.

deposits may yet be found in this locality as well as in other localities of *Lower Carboniferous* rocks.

LINCOLN COUNTY.

In Lincoln county, ores similar in nature but rather more promising as to their outcrops, have also been observed. In the Report of the Geological Survey of Missouri, 1872, Part II, p. 281, Prof. Potter has described these occurrences and his description of them is here quoted in full, since no developments have been made since his report was made.

Prof. Potter says: "Iron ore of excellent quality occurs in Lincoln county to a considerable extent, but the character of the deposits renders it improbable that it can ever be the source of an extended industry. After the completion of the railroads now in process of construction through the county, however, and with the consequent increased facilities of transportation, a large part of this ore may be shipped to neighboring metallurgical centers, and there command a good price."

Varieties of ores.

"These ores may be divided into two general classes according to their mode of occurrence.

I. Brown, hydrous oxides, occurring in crevices and in irregular cavities in the Upper Trenton limestones.

II. Compact red hematite in loose masses, scattered over the surface in various parts of the country.

The ores of class I are limited to T. 50, R. 1 W., as far as observed. On the land known as the Morris tract, several excavations were made a year ago, in one of which a considerable amount of ore was found. This occurs in a ridge north of Fort Spring Branch, in the receptaculites limestone of the Upper Trenton. A section of the strata at this place is here given."

"The annexed sketch, which represents a section through the bed, will show truer than a mere description, the character of the deposit. The depth of the cavity is twenty feet, and, at the bottom, a small passage leads off at right angles a distance of five feet. (A) represents the Receptaculites limestones, and (B), at the surface, a layer of barytes or heavy spar, from one to one and a half feet thick, the upper part in large crystal-

line masses with well developed crystals in the cavities, also a small amount of galena. The lower part is highly charged with oxide of iron, which increases in amount, the layer gradually passing into (C), an ochery brown, hydrated peroxide of iron quite compact, containing a little barytes. An analysis of an average sample from this layer afforded Mr. Chauvenet 63.12 per cent. of peroxide of iron. The layer is about three and one-half feet thick."

Iron deposits of Lincoln county similar to those of other Lower Carboniferous localities.

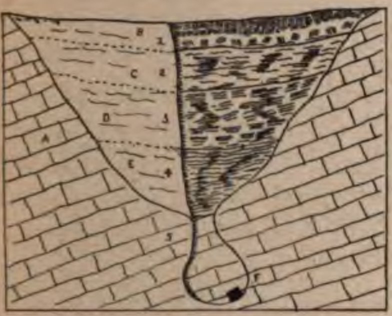

FIG. 35. Section at Morris iron bank in Lincoln county.

"Below this occurs five feet of (D) hard and somewhat cellular dark brown peroxide with slightly iridescent surface, and containing compact, bright red peroxide intermixed. It contains, by analysis, 79.64 per cent. peroxide of iron and 15.42 per cent. of insoluble matter, mostly silica. As this layer passes gradually into (E), a very hard cellular, dark brown and red hematite mixed, containing in some of the cells a thin, ochery deposit. It extends to the limestone below, and has a thickness of about seven feet, the amount of peroxide of iron reaches as high as 84.30 per cent."

"The greatest diameter of this deposit is about twenty, and its shortest eight feet. Nearly half of this ore has been taken out, and lies heaped up near the opening. For a distance of a mile and a half along this rise three other similar deposits were recognized, by the outcrops of masses of hydrated peroxide, but they are all limited in extent."

"The ores placed in Class II occur in many parts of the county, but they are most abundant between Big Dry Branch and Lead Creek. The ore is a hard, compact, red hematite, found in pieces, more or less flat in shape, from one to three inches thick, and weighing from one pound to one hundred pounds. These frequently lie scattered over the surface in broad, imperfectly defined streams, generally independent of present topography, though a larger amount is often found accumulated

Scattering fragments of kidney ore.

in the ravines and beds of streams. In such places the fragments are generally smaller and more or less completely smoothed, while, on the ridges, larger pieces occur with well defined edges and angles, on the top of the ground or distributed through the soil and gravel down to the limestones, but, in no case in the latter, the underlying limestone is generally the Archimedes though it is frequently the encrinital. There is no direct connection between the ore and the limestone. Many pits have been sunk where the ore is most thickly scattered, and it is found to give out on reaching the limestone. The ore, though in some places rather too siliceous, is generally of excellent quality, as appears in an analysis made by Mr. Chauvenet of an average sample:" —

No. 1.

	Per Cent.
Insoluble siliceous matter	7.55
Peroxide of iron	91.95
Sulphur	0.017
Phosphorus	0.010
Metallic iron	64.36

Two other samples from different localities afforded:

	No. 2.	No. 3.
Insoluble siliceous matter	11.60	4.10
Peroxide of iron	86.56	92 32
Metallic iron	60 59	66.72

The ore may be worth the trouble of collecting and shipping.

"This ore is spread over many square miles of surface, and in varying quantities; at some places a few scattered masses occur and at others the yield would be over one hundred tons to the acre. At some time it may be found profitable to gather this ore and ship it to neighboring iron works, and this could be done at little expense. A large outlay for the utilization of this material would not be profitable."

These fragments derived from other beds.

"These fragmentary masses of iron ore seem to have been derived from some higher formations, in which the original beds of iron ore existed. Whether this formation was one of the upper limestones of the Lower Carboniferous series or the Ferruginous sandstones, or of the Coal Measures, it would be

difficult to determine; it was, however, more recent than the Lower Archimedes limestones."

"This formation, which originally contained the beds of ore, has passed away through the action of erosive agencies, leaving the heavy and more durable ore behind. From the sharp and well defined outlines of the fragments it is very improbable that this ore could have been transported to any distance."

More rapid erosion along the Mississippi has removed the formations which remain intact in other localities.

This quotation shows very clearly that the writer's opinion is closely in accord with Prof. Potter's. It is very probable that the more rapid erosion along the line of the Mississippi river has entirely removed the sandstones in which this ore occurred, together with the softer parts of the ore bed itself. The reason for the assumption that the original rock was a sandstone of the Coal Measure formation lies in the fact that, in Callaway county, and to a greater or less extent in Cooper, Saline, Henry and St. Clair counties, a precisely similar ore occurs interbedded with a sandstone which lies on the crinoidal limestone. Along the sides of ravines and on the banks of water courses, fragments of hard red ore occur. They are smooth surfaced, but, at the same time, often angular in shape. In many of these hills no sandstone is found, and here will be found the ore fragments. Wherever the sandstone appears the ore fragments are not found except on the banks of ravines as before mentioned.

CALLAWAY COUNTY.

Test shafts on M Dunn's farm show an extensive bed horizontally.

In Callaway county, several test pits have sunk down to and through the ore body. On the farm of Mr. Raph Dunn, township 46 N., 10 W., Sec. 32, prospecting has covered twenty acres at least. This has been done at various times extending over a period of twenty years. Even on the level near Mr. Dunn's house the deepest shaft was only thirty-two feet. The shallowest was eleven feet. Both of these shafts struck the iron ore and passed through it. This ore body was, as reported, seven feet in thickness. These shafts, as well as others, are now filled with water and no personal verification could be made; but Mr. Dunn reported that, after going through from five to seven feet of clay with chert, they struck a "gravel bed," which, for

the last two feet above the iron ore, was so hard that it had to be drilled and blasted. About six hundred feet east of the deepest shaft is a narrow gorge which runs south till it joins a large ravine running east and west. At three places in this ravine the bedded hematite crops out at the surface. On the east side of this gorge (see Fig. 36, a drawing from a photo-

Hematite crops out in three places.

FIG. 36. Sketch of the Raph Dunn bank, in Callaway county. *From a photograph.*

1 is sandstone with fossiliferous pebbles.
2 is the ore body with dark kidney ore and soft red hematite.

graph), the outcrop is so plain as to leave no doubt as to its relation to the other rocks. As will be seen in the figure, from above down, there is, 1, a loose bed of water worn pebbles which become quite firmly cemented towards its bottom. This gradually merges into a bed of fine shaly sandstone. This shaly sandstone lies immediately upon, 2, the ore body. The ore body consists of two distinct parts, a loose crumbly red ore and, second, distinct lenses of hard, compact red hematite. The lenses of ore vary from five inches to two feet in longest diameter and from three to ten inches in thickness. This lens-shaped or "kidney" ore makes up about one-fourth of the entire bed which is, as nearly as could be measured, about seven feet thick. This bed seems

Ore body consists of two parts.

to be nearly horizontal. Across the ravine, about one hundred feet distant, are two other outcrops of what is probably the same kind of ore and they are overlaid by beds of shaly sandstone and conglomerate. They also are about seven feet thick. These beds, however, do not lie horizontally but dip towards each other, though a shaft, dug on the hill west of these, shows iron which is reported to lie horizontally. No contact of the iron beds with underlying rocks is to be observed here, but in these instances the underlying rock is probably limestone. Limestone certainly shows in the gorge a few feet below the mine openings and thence clear to the bottom of the ravine to the south. The limestone is crinoidal and layers of chert in the limestone are highly fossiliferous. The conglomerate, which overlies the iron ore bed, is made up of fragments of sandstone which are also fossiliferous. The relations of the iron ore bed to the rocks above and below are shown in the following section.

The shafts show the ore to be interbedded with sandstone and probably limestone.

FIG. 37. Section at Raph Dunn iron bank.

This varies considerably from the section which Dr. A. Schmidt gives of the mine on Shaft hill, on the south side of the ravine. Dr. Schmidt's section is given below for comparison.

FIG. 38. Section at Shaft Hill.

On Shaft hill the ground is now entirely fallen in, thus obliterating all means of comparing the two localities.

As this locality has not been worked since 1872, Dr. Schmidt's report is here copied in part: "This hill of which a geological section is given (see Fig. 64) is one of the most hopeful and one whose structure is most clearly seen in this district. The limonites, sandstones and conglomerates are exposed in several places forming a high bluff. The ore and the strata overlying it are not exposed, and have to be judged from pieces found on the surface. Fragments of this ore are found at a certain level all around the hill. A stratum of ore undoubtedly runs entirely through the hill and the thickness, from the surface indications, be estimated from one to three feet. In some places, however, it seems to reach a thickness of five feet. The hill is nearly round and has, at the level of the ore bed, a diameter of about eight hundred feet."

Shaft hill resembles, in its principal points, Dunn's shaft.

The quality of the ore may be assumed to be the same as that found on the north side of the ravine at Raph Dunn's bank. Two analyses of the latter ore, personally selected by the writer and analyzed by the St. Louis Sampling and Testing Works, is as follows: —

	SLATY GANGUE.	HARD KIDNEY ORE.
	Per cent.	Per cent.
Insoluble matter	6.95	9.66
Metallic iron	43.17	57.20
Phosphorus	1.296	0.07

It will be noticed that Dr. Schmidt does not describe a layer of sandstone *above* the ore body, while at the Raph Dunn bank this is distinctly observable. Further, he observes a thick bed of sandstone and conglomerate *under* the ore body, while, at the Raph Dunn bank, though the underlying rock is not visible at the openings, it is judged to be limestones, since the difference in level, between the outcrop of iron and the unmistakable outcrop of solid limestone, will not admit of a thick bed of sandstone lying between the two. These discrepancies may be readily understood, for it is by no means difficult to imagine that a bed of iron might oscillate in position, a continuous bed lying at one time under a bed of sandstone and at another time above it.

The difference in the two sections may be explained by oscillation in deposition.

The discrepancies in observation as to thickness may doubtless be explained in the same way. Sandstone is found very abundantly on the surface of the ground in many places in Callaway county, while limestone is not so common, except in ravines and in water courses which have cut below the general level.

COOPER COUNTY.

Numerous outcrops of an iron ore similar to these already described are found in Cooper county, along the banks of the Lamine river and Black Water creek. The circumstances of their occurrence are also similar. Going down, from the general level of the county, into one of the ravines or river bottoms, one finds, on the surface, blocks of ferruginous sandstone, often fossiliferous, and large angular blocks of chert containing beautiful impressions of crinoid stems, and oftentimes perfect heads, sponges and brachiopods. No conglomerates are certainly observed, and, finally, the crinoidal limestones with highly fossilliferous chert is found in place. No outcrops of iron have been seen which could certainly be called original bedded deposits, although kidney ore is occasionally met with. No ore has ever been dug for shipment, and only a few unimportant holes have been opened, and these years ago, to guide the observer in his estimates. The ore that has been thrown out is a loose porous hematite which, in most places, has been completely changed to limonite. As the ore is thrown out with fragments of sandstone and from shallow pits we can infer that it here is a bedded deposit although it may be much disturbed by undermining. Farther than this, it lies near the surface of the ground and with disintegrated and broken sandstone. It is, therefore, very possible that the iron remaining is the hard part of the bed, such as is found in the Raph Dunn bank, and that the softer and more friable part has been removed by solution at the same time with the breaking up of its overlying sandstone. If this is the case, then, in the higher points of the county, at a greater distance from the heavy drainage of streams like the Lamine river and the Black Water, beds of ore may possibly be found intact. There are few surface indications, however, and no exploring

Loose masses of porous hematite mingled with sandstone and chert suggest that beds of iron once existed here.

work has been done. It may be stated in general that there are a great many stony or rocky hills near these streams where porous, red hematite in scattered fragments, as well as kidney ore, are quite abundant.

SALINE COUNTY.

In Saline county, township 48, range 18 N., Sec. 15, there is a thin bed of hematite which crops out in the bed of a brook. The hematite seems to lie, at times, on a crinoidal limestone and then, at other places, to be separated from the limestone by a thin stratum of highly ferruginous sandstone. The hematite bed itself is not over five to ten inches thick, but is of a very brilliant red color and is very pure. Overlying it is about ten feet of incoherent water-worn sand and pebbles, probably a decomposed sandstone. The only work that was ever done here was about ten years ago, when a few tons were taken out and shipped to Chicago. It was probably used as a paint ore. There are many signs of iron in small quantities in numerous places, but beyond the fact that the outcrops point more certainly to a regular bedding, there is no essential difference between the localities in Saline and those in Cooper county. In the greater number of localities this ore has been wholly changed to limonite.

Scattering deposits of hematite ore found in this county.

BENTON, HENRY AND ST. CLAIR COUNTIES.

Following this same formation through Pettis, western Benton and eastern Henry counties to St. Clair county, there are in many localities traces of red hematite and sometimes of kidney ore. In St. Clair county this is especially true along the borders of the Osage river, and, in Henry county, on the divide between the Osage and the Grand rivers, fifteen miles east of Brownington on the Brownington and Warsaw stage road. From Hillegus prairie to within a short distance of the ford across the Osage river the surface of the ground is covered with large blocks of chert. This chert is made up almost entirely of crinoid stems with casts of crinoid heads, bryozoans, brachiopods.

The Lower Carboniferous extends through Benton, Henry and St. Clair counties.

sponges and corals. In places sandstone appears bedded, but much broken and usually dark colored. Along the steep slopes of the divide, either towards the Osage or the Grand rivers, the chert and sandstone give place to heavy beds of crinoidal limestone with brachiopods and large coiled shells.

The iron ore in this locality is found lying on the surface, either mingled with sandstone and chert or lying a little below the crest of the slopes and in scattering blocks on the surface of the limestone. The greater part of the ore seems to be siliceous and changed to limonite. In places it seems to cover the entire surface of the ground over several acres in extent. In this case the ore is a mixture of limonite and porous red hematite. There is no means of judging of the thickness of these deposits, for no exploring work has been done. In one or two places there has been some ore dug and carted to the banks of the Osage river, but this was done over twenty years ago and the holes have all fallen in. At that time the iron works on the Osage river promised to be a consumer of these ores and prospecting was to a considerable extent stimulated, but, with the destruction of these works by fire, all efforts at development ceased. From the study of this locality, in the light of the exploring done in Callaway county, there can be but little doubt but that the red hematites found here are true bedded deposits. From the fact of their number and their association with the sandstone and crinoidal limestone it is inferred that these deposits all belong to the same stratum, or, in other words, that this bed or stratum is continuous. Farther than this it is also highly probable, by analogy, that these beds are not of great thickness. The relations of this bed to its accompanying rocks appears to be as follows:

Ore found on the surface in blocks.

Red hematite curring as above has been dug and shipped to some extent.

FIG. 39. Section across the divide between Grand and Osage rivers.

1 = Sandstone.
2 = Kidney ore in soft red hematite.
3 = Beds of cherty limestone interstratified with pure limestone.

CONCLUSIONS.

The Source of the Ores. From the description of the Callaway county ores it will be seen that in all probability Prof. Potter is quite right in assuming that the red hematite ores of Lincoln county are the remnants of a younger series of rocks that formerly overlaid a part of Lincoln county. The kidney shaped, hard, compact nodules are the same as are found in places in Callaway county, and these ores are here seen to be interbedded with sandstones and limestones. If additional proof were needed it can be found in other localities of the Lower Carboniferous, where such rocks are found in almost every stage of disintegration, even to the removal of all traces of the formation save some scattering fragments of compact red hematite as, for instance, just across the Osage river from Warsaw in Benton county.

It is concluded that these red hematite ores are bedded deposits.

The value of these ores lying in the localities above named is entirely relative. It depends upon: 1st, extent; 2nd, cost of mining; 3d, transportation to points of consumption. These questions will be considered fully in the chapter on "Limonite Iron Ores." What is true of them is also true of the red hematites. The points there outlined will, however, be briefly reviewed here.

The value of these ores depends upon extent, cost and accessibility.

The Extent of the Deposits. As to the extent of the deposits areally this is indicated by the extent of the geological formation with which they are associated. The outcrops are by no means of brilliant promise. The ores are fair in quality, but they are not so pure as to force exploration in the face of doubtful success. Their outcrops are not so extensive, nor on so large a scale as to stimulate prospecting with an eye to the establishing of large iron works, depending on these deposits as a source of ore supply. On the other hand, they are bedded deposits and they can be reckoned on as extending for a considerable distance, radially and horizontally from any given outcrop. The depth to which a prospect hole must be sunk to test the thickness of the bed will nowhere exceed forty feet, and

usually will not be more than ten to fifteen feet. These prospect shafts will not be sunk in hard rock, but in a soil of such a tenacity that little or no timbering need be done if the hole is put down continuously, that is without the cessation of work for a few months at a time. Finally, if the ore bed lies upon a limestone rock prospecting can cease when this is reached with the full confidence that whatever the result, there is no need of going deeper. It will thus be seen that the expense of testing a large area in this manner will be very slight. Testing in the manner indicated is the only way of determining the extent of such deposits.

On account of meager demand for iron little is known, practically, of the extent of the ores.

The Cost of Mining. Another factor in the value is the cost of mining. In the present state of the iron market a bed of rich iron ore three feet in thickness, tolerably near a furnace, could not be worked. Underground mining could not be carried on without the removal of much rock and this would be slow work and a ton of rock would cost as much as a ton of ore. No definite limit can be fixed. It may throw some light on the question when it is said that, at Birmingham, Ala., the beds of iron ore are in many places twenty-two feet thick. As the beds of the state in the Lower Carboniferous vary from less than three feet upward, it is a question well worth considering, whether the cost of mining would not at present, at least, equal the value of the ore. When the deposits lie on the surface or can be exposed by a few feet of stripping the question of the cost of mining disappears and that of accessibility claims consideration.

No estimate can be fixed as to cost of mining.

Accessibility of the Ores. In Benton, Henry, and St. Clair counties the proximity to the Osage river seems to at once settle this point. Ores, if found in considerable quantity, could be very easily shipped to furnaces in St. Louis, or, in case of the rebuilding of the Osage Iron Works, a much nearer and more profitable market could be had. The Callaway ores after a short rail transportation could be floated to St. Louis.

The ores if abundant are easily accessible from the Missouri river.

The important question for the present, however, is that of extent. If every property owner would put down vertical shafts

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on his iron outcrops and note the thickness of the bed, there would be very soon data upon which reliable estimates could be made. These prospect shafts as already pointed out could be made at slight expense and would very soon settle the whole question as to the value of the iron prospects in the Lower Carboniferous rocks.

CHAPTER V.

THE GENERAL GEOLOGY OF THE OZARK UPLIFT.[1]

THE OZARK MOUNTAINS — THE STRATIGRAPHY OF THE OZARKS.

The two preceding chapters have dealt with ores which occur in the Archæan and Carboniferous formations, in the eastern and northern portions of the State. The ores which are the subjects of the two succeeding chapters occur largely within the area of that interesting central portion of the State termed the Ozark mountains. A discussion of some features of the geology of this area relating particularly to the subject in hand, is, hence, appropriately introduced here. A. W.

THE OZARK MOUNTAINS.

Area and General Characteristics. The term, "Ozark Mountains," has so persistently crept into literature, both lay and scientific, that it is exceedingly difficult to be gotten rid of. The area to which this name is applied is mountainous in name alone. It is a great, elliptical, dome-shaped rise extending, along its major axis, from near St. Louis, S. 76 W., to the southwestern part of the State. Along the minor axis the distance across the Uplift is about one hundred and forty miles.' From its highest point, which is at Cedar Gap on the Kansas City, Fort Scott, Memphis and Birmingham railroad, to Mammoth Springs, on the same road, there is a descent of about eight hundred feet in fifty miles. From Cedar Gap to the Missouri river, near Jefferson City, the distance is about one hundred and fifty miles with a descent of eleven hundred feet. Following a straight line down the northwestern and southeastern slopes the distance would be shorter by about fifty miles, and the average slope of the Uplift toward the southeast would be a little more than one degree while to the northwest the slope is less. This slope,

The Ozark uplift is a gentle fold running S. W. from St. Louis across the State

[1] For this very expressive name we are indebted to Prof. G. C. Broadhead of Columbia, Mo.

though all sufficient to produce a torrential flow in a stream flowing directly down it, is offset by the fact of the meandering courses of the rivers; their flows, though swift, are, therefore, not torrential. Current river, the swiftest of these streams, is declared navigable to Van Buren in Carter county. It could be navigated even further were the volume of water greater. The same may be said of the Gasconade and its branches, the Big Piney, Roubidoux, etc. There are no water-falls in any of these streams, nor in fact, are there great rapids. They can be followed in skiffs from source to mouth.

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Topographic Sub-divisions. Topographically the region of the Ozarks may be readily divided into 1st, a plateau region, 2d, a hilly or mountainous region, and 3d, into a region of river bottom.

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The plateau region occupies the crest of the Uplift and near it, or in it, the streams have their origin. The counties of Dent, Crawford, Texas and Wright cover nearly all of this area. The country here is hilly and constitutes what has been known as the "Second Sandstone region." The area for the greater part is a fine one agriculturally. The surface, gently rolling for the most part, is well drained naturally, but at the same time the hills or rolls are not steep enough to prevent easy tillage on the steepest slopes. By referring to Sections 1 to 3 in the accompanying plate of sections the two facts above pointed out will find confirmation, *i. e.*, that the hills are not high and that the region is essentially a sandstone one.

Following down the streams in either direction, however, we note that the bluffs grow higher and higher, the streams more numerous, and we pass, by insensible gradations, into a country cut up by deep cañons or gorges with steep walled divides. We are now in the area which gives the Uplift the name of mountain. While at the base of these steep sided hills we cannot escape the feeling that we are among mountains. A climb up the slope dispels the idea, however. Instead of a commanding view from the summit of the divide we look forth upon what in the distance appears to be a plain stretching away on every hand. The mountain crests rise to the same level as far as the eye can reach. Barometric observations made as one floats down the

stream show the bluffs and the hills which shut one in, growing higher and higher, and steadily but clearly the fact grows upon one that these mountains and hills have not been thrust up by orographic movements, but that they have been etched into relief by the slow action of the streams which flow among them. Farther away from the plateau head-waters the streams grow more numerous and cut deeper and deeper towards the drainage level. This leaves the country cut up into long, narrow, sharp-crested ridges with steep chert covered sides. Another topographic feature in the plateau region is the valley. There are not many examples of this feature of the Ozarks and it only exists where there are no large streams, or, where there are no streams at all on the surface. These valleys, when they do exist, are limited in area, as for instance Hutton valley in Howell county, but they are fertile and easily tilled. They exist for the same reasons that the plateau region exists, simply because no large stream has cut deeply into the rocks; the water being carried off by underground drainage as will be pointed out later.

Deep gorges d velop down slopes from plateau regi

Following the streams from the plateau regions into the mountain region, so-called, we find that the development of river bottoms begins. At first narrow and of little value, they gradually widen out until the hills begin to be secondary and the bottoms spread out into river plains of from one-half of a mile to two miles or more in width. The hills lose their sharp crests and steep slopes, there are few rocky ledges exposed, and the river bottoms, by an easy slope, gradually rise above the flood plain to the higher and hardly less tillable upland. Doniphan in Ripley county, Puxico in Stoddard county, Poplar Bluff and Neelysville in Butler county, are good examples of this surface modification by streams. Here the hills are nearly base-leveled, the divides growing lower and with more gentle slopes, until, in the country east and south of Poplar Bluff, they have been lowered to scarcely perceptible ridges. On the northwestern slope of the Uplift the same set of conditions prevail; but as to rocks and general surface configuration the details are greatly modified. Along the Gasconade and the Osage rivers there are wide fertile flood plains, but away from these plains the ground

The gorges or canions grad ally widen in river bottom

rises rather steeply. The hills are high with moderately steep slopes, but comparatively few rocky ledges are found, and the hills are tillable for the most part to near their summits. These summits are usually capped by sandstone, more or less broken, and these fragments yielding less readily to the action of the elements, make the ground too rough to be available for tilling.

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But the most striking difference between the two regions is that on the southern slope, the river bottoms are of easier grade and are often swampy; while, on the northern slope, swamps are practically unknown. Gasconade, Osage, Cole, the lower parts of Maries and Miller counties, are good examples of the steeply rolling country with rich farms lying along the river bottoms.

The Soils. The soils of the whole region are clayey or loamy. Sandy soils rarely exist. On the slopes and summits of the steeper hills chert is so abundant, owing to the washing away of the soil, as to prohibit cultivation of crops, although fruit trees do well. These facts can be well appreciated when it is remembered that the whole of this region lies below the line of glaciation and that the soils, with the exception of the river bottoms, come entirely from the rotting of the rocks in place. The rocks are limestone principally, except in the sandstone regions,

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and the soils are thus residuary, the insoluble portions of the limestones. The river bottoms, of course, are also made up of the debris washed from the hills. It would follow, therefore, that over these bottoms the soil would be deeper and richer. In addition, nearly every freshet raises the water over the banks of the stream whence it flows over the entire bottom, and standing or only slowly retreating with the fall of the stream, a fine deposit of silt is left. Even where the bottoms are narrow the fertility is great year after year, and, unless the crops are destroyed by storms, heavy fields of wheat and corn or oats are raised, although fertilizers are never applied. The last is true of the uplands, but the crops are never so great, though, not being subject to floods, they are more sure, and though the continuous wash from the hills renews the soil, this is to a less degree than in the bottoms.

The Drainage. Like many other features of this section the

streams are peculiar. Springing, in many cases, abruptly from the foot of a tall cliff they emerge from underground as large-sized springs and begin cutting their channels at once. As has been briefly pointed out, they flow in deep cañons or steeply sloped gorges. These gorges are shallow when the streams first start on their courses. Gradually they grow deeper and deeper till they are shut in on either hand by steep limestone or sandstone cliffs which often reach a height of three hundred feet. It is not uncommon for a bluff to rise, by a succession of precipices of from fifty to one hundred feet fall, to a height of five hundred feet. A bluff on one side of the stream has usually, in the lower courses, a level bottom opposite, and, as its flows along, it turns from bluff to bluff in an exceedingly tortuous course. With the widening of the bottom the streams grow more winding. At one place on the Osage river, by leaving it and passing by land, the river is intercepted in less than one mile while the stream itself flows seventeen miles to reach the same point.[1] This is an extreme instance of a winding course, but a departure from a direct line of from three to seven miles in the principal streams of the Ozarks is not at all uncommon. The reason of it is not far to seek. The almost entire absence of folds in the rocks has left the streams to cut their own way along the lines of least resistance. Instead of being guided by dipping rock walls they have cut vertically through the horizontal rocks. Whenever a more soluble or friable stratum has been reached the turning stream impinges sharply against this yielding stratum, and the undermined and falling cliff preserves its precipitous front, and thus gives rise to the river bottoms at the same time.

The streams flow through gorges which were once caverns.

Windings caused by horizontally bedded rocks.

The absence of boulders is another noticeable feature of the streams. This, too, is readily accounted for. The undermined cliffs tumble great rock masses into the stream, but these boulders are either soluble limestone or friable sandstone, and in either case they are soon removed.

The streams of the Ozarks are almost without exception of rather large size. There are few perennial small streams south

[1] This is not an instance of flood plain meandering, but the country included in the loop of the river is hill-land, bordered by bluffs. A. W.

of the Missouri river, such as are known as brooks in the eastern part of the country. In this respect it presents a striking contrast to hilly or mountainous countries elsewhere. There are many water courses visible on the surface but there is no water in them generally. Yet these same water courses may, in three hours' time, be swelled with impassable floods. As an instance of the rapid rise of the larger streams, as well as of the smaller ones of the Ozarks, it may be mentioned that the Big Piney in May, 1892, rose twenty feet from 4 p. m. to 12 p. m. The Current river during the same month rose twenty-seven feet in about the same time. The cause of this rapid rise of the constant streams, as well as of those which may be referred to as ephemeral, is very plainly to be seen when once one is familiar with the region. The hills are cañon formed and consequently steeped walled. Even a gentle rain keeps the rocks nearly washed bare of soil. To heavy rains the thin soils, even when held in place by the scant vegetation, and the all but naked rocks, present little check to the water and in the course of a few hours the entire rainfall will be poured into the narrow stream bed. The floods subside almost as suddenly as they rise. On the hillsides there is no soil to hold back the water and to give it up little by little in the form of brooks, and, in the valleys, or what would correspond to them, the water sinks through the soil and then percolates through the porous rock floor of the country to appear later in the form of springs. Even with this brief and imperfect description one can imagine the powerful erosive effects of this drainage system. But to float down one of these turgid streams and to hear the incessant grinding and knocking of sand and pebble in the swirling water one can gain an idea of its power which words alone will fail to convey.

Springs and Subterranean Erosions. Another important factor in the development of the topography of the Ozark mountains are the great springs. For these phenomena the country is well formed. Given the easily soluble limestone rocks; and an uplift whose slope is so gentle as to preclude torrential streams, the rapid flow of which takes away the water before its solvent powers can produce an effect, and here are the ideal conditions for the elaboration of an underground drainage system on a vast

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scale.[1] The springs are widely distributed, as might be expected from the contour of the country. In the plateau region, as first described, springs are few in number and only moderate in size, unless they open out into deep drainage gorges, as the Meramec spring opens into the Meramec river. Along the borders of this area, however, where the mountain belt often begins abruptly, the springs are more numerous and of large size. One, for instance, known as the Meramec spring, six miles south of St. James, Mo., is reported to flow 10,000 cubic feet per minute.[2] Current river bursts from the foot of a large hill in a stream no less in size than the Meramec spring and, twelve miles from its source, its volume is more than doubled by another spring rising from under a limestone bluff. Greer's spring in Oregon county, Big spring in Carter county, Mammoth spring, on the Arkansas and Howell county line, Roaring spring, Pulaski county, Cave and Round springs in Shannon county, are a few of the great springs which may be mentioned. These, however, constitute but a small fraction of the total. Practically, Current river, Big Piney, Eleven Point, Jack's Fork, Little Piney and Spring river are all spring-fed streams. They do not increase in volume by visible tributaries but receive constant accessions to their volume by means of almost innumerable springs of variable sizes.

Springs not as numerous in the plateau as in the mountain region

Springs are of great size.

These springs are, of course, but underground streams that in this way make their first surface appearance. Their underground courses are, in fact, frequently disclosed. In the famous Marble cave, in Stone county, a large stream flows through the cave. Near Thayer, in Oregon county, is a place known as Grand Gulf. Here there is a large underground stream visible for a short distance, and this is generally believed to be, and probably is, the feeder of the Mammoth spring in Arkansas. Sinking creek, in Shannon county, flows as a surface stream for a long distance. A few miles from where it empties into Jack's

Proofs of the existence of underground streams.

[1] This may seem to contradict what is said on p. 6. If, however, it is remembered that the springs rise almost as rapidly as do the surface streams the statements will lose their contradictory appearance. It is only the heavier rainfalls, "cloud bursts" as they are called, that fill the surface water courses with floods. The rains for the most part make their way through subterranean caverns to appear in the rivers in the form of springs.

[2] Dr. A. Schmidt, Report Geological Survey of Missouri 1872, Part I, p. 145.

Fork it runs into a *cul de sac* formed by a crescent-shaped mountain five or six hundred feet in height. Just before reaching this mountain it sinks from sight and reappears a mile away on the other side of the mountain in the form of a large spring. There are numerous other instances which might be cited, but enough has been said to amply suggest the reasons for the conclusion that the whole of the Ozark system is undermined and honey-combed by underground waters. If further testimony were needed it may be had from the fact that many of the smaller springs, and some of the larger ones, emerge from caverns, a few inches to several feet in height, which come from unknown distances under the bluffs from which they emerge.

lisappears round.

From these known causes and their visible effects we can reason back to the past with the full assurance that underground waters have played an important part in shaping the present topography. From the foot of almost every perpendicular bluff to near its summit the heavy limestone is completely honey-combed with cavities of various sizes, some of them being large caves reaching far into the bluff. From our observations of the springs which now exist at water level, we can imagine that these too were once subterranean flows before the stream had cut its way down to its present level. Farther down the stream where the bottoms begin to widen, the bluffs are covered with a talus of broken rock and only occasional beds of rock are visible. But from the often disturbed condition of these rocks we can imagine that here a still more advanced stage of underground erosion has been reached leaving an unsupported roof to break and fall in. Not quite as noticeable, but yet very apparent, is the disturbed condition of the sandstone in the vicinity of a spring, and the broken fragments that cap the more isolated hills farther down the stream. All these facts, in the light of the knowledge which we have gained from the now active springs, point to the same erosive action. In the plateau region we can find even now traces of springs, but they are small in size and feeble in action as compared with others farther down the slopes of the Uplift.

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The [illegible] It may be asked what effect has this topography on vegetation? In general it may be answered that the

quantity and depth of the soil are the controlling factors. The soils, when present, are rich enough and the rainfall sufficient to insure a heavy forest growth of the most valuable kind, but, on the summits and steep slopes of the hills, there is either no growth of forest trees or at best it is light and stunted. This is due to the fact that the soils are kept thin by continual waste and are thus of insufficient depth to support a more rugged growth. Nearer the base of the hills the growth begins to get heavier and in the river bottoms there is a dense growth of gigantic trees. Twenty or thirty years ago these hills are reported to have been entirely bare of forest growth and were known as "Bald Knobs." At present these "knobs" are covered by a stunted growth of what is locally known as "Jack oak." This growth is interspersed with hickory, cedar and yellow pine. The forest here grows very open and the ground is covered with a heavy growth of "prairie grass" and many flowering plants. The growth in the bottoms is principally sycamore, gum, elm, water maple, water birch, ash, hickory and a great number and variety of oaks. In addition to the natural density of the forest growths the great number of vines make it almost impassable.

Vegetation is affected by washed and shallow soils.

The Rocks Composing the Uplift. The geological horizon to which nearly all of the rocks of the Ozark Uplift belong is the Cambrian, and more specifically designated, to the Ozark series.[1] As will be shown later on these Ozark rocks have been considered to correspond to the Calciferous sandstone of New York State. Though the Cambrian strata form the great bulk of the rocks of the Ozark region, other formations are also represented. On the northern and western slopes of the Uplift lie rocks of the Lower Carboniferous age. These rocks are by no means wholly confined to the flanks of the mountains but, along the line of the Kansas City, Fort Scott and Memphis railway, they reach at least two miles east of Cedar Gap, the highest point of the Uplift. An outcrop of this rock is reported to lie on the rocks of the Ozark series near Rolla. Chert fragments with characteristic fossils are found throughout the whole region, capping the highest hills. It is thus very probable that, to a greater or less thickness, the rocks

The Ozark series are of Cambrian age.

[1] See pp. 12 and 17, foot note.

of this formation at one time extended over the whole Uplift. Lying around the borders, also, are found occasional deposits of coal of limited size. These deposits, or pockets as they may more properly be called, are found quite numerously scattered through the mountains.[1]

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Though the great area of Archæan rocks lies, properly speaking, beyond the recognized limits of the Uplift, these rocks, consisting of granites and porphyry, are found far within the boundary lines. In Shannon county, along Current river, from a little above the mouth of Jack's Fork and down to Van Buren, in Carter county, the porphyry rocks are frequently exposed. Between the mouth of Jack's Fork and Eminence, Shannon county, are numerous outcrops. Granite is also found three miles below Van Buren on the Current river. In Camden county, township 37 N., 16 W., Sec. 32, is a small outcrop of graphic granite. This is the only outcrop of the kind which has thus far been observed in the State.

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The Minerals of the Region. The minerals of economic value which are found in the Ozark region are lead, zinc, iron, coal, manganese, copper and silver. Lead and zinc, in the form of sulphides, are found widely disseminated throughout the rocks of the Ozark series. They are found in veins and pockets and are certainly of secondary origin. That they are secondary is proved by the facts that they are found with calcite, ("tiff,") and barite, in well-defined crystals and with marcasite and pyrite, lining cavities or pockets and along the walls of veins in the limestone rocks. Iron in the form of limonite is found widely and abundantly distributed throughout the whole area. Specular ore is found in the plateau region of the Uplift and also in the porphyry rocks. These mineral are discussed fully under the head of Limonite, etc., in the following chapters. Manganese is also widely distributed, but, unfortunately, so far, it has not been found in workable quantities. It occurs as a cementing material in sandstone in Howell county in a number of localities. It also occurs in the veins in the porphyry near Pilot Knob.[2] It has

[1] For a fuller description of the geological relations of these rocks, see Bull. Geol. Soc. Am., A. Winslow, Vol. 3, 1891.

[2] Prof. R. Pumpelly, Rep. Geol. Sur. Mo. Part I., p. 20, *et seq.*

also been found of remarkable purity in veins in porphyry in Carter county, township 28 N., 2 W., Section 31, but the veins are far too small to be worked with profit. At the same locality, on the land of the Missouri Lumber and Mining Company, manganese is found cementing a chert breccia. The greater part of the slope of the hill is covered with residuary clay and chert. The manganese is, however, confined principally to the chert. A shaft has been sunk on this property. The chert carrying interstitial manganese is about ten feet thick. Below the chert is a gritty clay with occasional small nodules of manganese. An analysis of the chert breccia gave 25 per cent. of manganese and 50 per. cent of silica. Several other openings have been made but with no better results.

As may be inferred from the fact that the rocks of the Ozark Uplift belong to the Cambrian age, there is practically no coal in this region. Coal has been found in numerous pockets of limited size, as already referred to, but even with this positive testimony, it can safely be said that no extensive beds will be developed. Coal is found in pockets.

Near Eminence, in Shannon county, it is reported that copper ore in form of the double sulphide, chalcopyrite, has been found and mined to some extent. However this may be, none is now mined and the exact locality has not been reported to the Survey. Near St. Clair, in Franklin county, the oxide with some carbonate, both occurring with a decomposed specular ore, is being exploited at the present time. Numerous signs of copper are found.

Although properly not within the Ozark region, silver has been found in the granites, in Madison county. With the exception of the very small amount of silver which is always associated with galena, or lead sulphide, this is the only occurrence of silver known. Gold has never been found and it is a metal which is probably entirely foreign to this area. Silver found in the granites.

Leaving now this rather brief general description of the Ozark Uplift, let us turn our attention to the details of the geology.

THE STRATIGRAPHY OF THE OZARKS.

Reference has already been made to the occurrence of beds of sandstone and limestone which make up the greater part of the

rocks of the Uplift. The sandstones occur in such a way, apparently at least, as to make convenient datum points by means of which the associated beds of limestone can be correlated. This correlation has been made in the following manner. Starting with the Lower Carboniferous limestones, which are fossiliferous and are thus easily identified, it has been observed that these rest, in places, uncomformably on a magnesian limestone. Second, beneath this limestone a heavy bed of sandstone has been noted. Next, another bed of limestone, also magnesian, is found; and so on until four beds of magnesian limestone have been reported as alternating with these beds of sandstone. The following section (Fig. 40) compiled from Prof. Swallow's re-

limestones sandstones guised by earlier ogists.

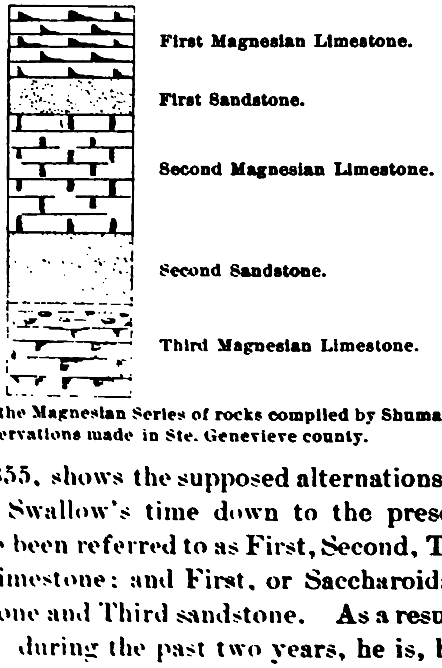

FIG. 40. Section of the Magnesian Series of rocks compiled by Shumard from observations made in Ste. Genevieve county.

port, published in 1855, shows the supposed alternations of these rocks. From Prof. Swallow's time down to the present time alternating beds have been referred to as First, Second, Third and Fourth magnesian limestone; and First, or Saccharoidal, sandstone, Second sandstone and Third sandstone. As a result of the writer's observations during the past two years, he is, however, led to the conclusion that the reasons advanced for thus separating the formation by means of the sandstones are insufficient. The paucity of fossil remains lead the earlier geologists to have recourse to identification by means of lithological characteristics, and these, in any case, are very unsatisfactory. Thus, the name, Saccharoidal, has been applied to the first sandstone. The fact

were iden by litholog character s only.

that the sandstones at Pacific, Mo., and at Crystal City and other places, assumed to be First sandstone, are so friable as to be easily crushed in the hand, led to the adoption of this term as a distinctive name. But, in the so-called Second sandstone region, of Crawford and Dent counties, not to mention other well-recognized localities, the sandstones in many localities are quite as friable as are those at Pacific, Mo.

Earlier Correlations and Descriptions. Mr. Meek, in his report on Moniteau county,[1] thus refers to the First or Saccharoidal sandstone: "The rock I have supposed to be identical with the above, is, everywhere in Moniteau, excepting in a few instances where it is very thin, a heavy bedded more or less friable sandstone. It is usually indistinctly stratified, and varies in color, from nearly a pure white, through various shades of yellow, to a kind of dusky brown.

Mr. Meek refers to First sandstone in Moniteau county.

"Sometimes it contains enough calcareous matter to cause feeble effervescence when acids are dropped upon it."

Dr. Shumard in his report,[2] refers to the Saccharoidal sandstone as follows: "The first of these, beneath the 1st Magnesian Limestone, is the *Saccharoidal Sandstone.* * * * It will be seen that this division of the Calciferous Group prevails to a considerable extent in this county, and particularly in the northwestern quarter, where it occupies the summits of nearly all of the highest ridges."

In the report of the Geological Survey of Missouri, 1855 to 1871, there are numerous references to the Saccharoidal sandstone as well as to the other sandstones of the Magnesian series. On page 10 of Prof. Broadhead's report on Maries county he refers to this rock as follows: "I was able to identify this rock only in the eastern part of the county. I first observed it on Spring creek, Sec. 16, Township 39, Range 8 W., where it occurred on the summit of a very high ridge as a small patch of about three feet in thickness." In the same place he mentions having found an Orthoceratite in a piece of ferruginous sandstone. On page 26 of the same report,

References to Saccharoidal sandstone in the 1855 Report.

[1] Second Annual Report of the Geological Survey of Missouri, G. C. Swallow, State Geologist, Part II, p. 105.

[2] *Ibid.*, p. 160.

Prof. Broadhead again refers to this sandstone in Osage county: "This formation is found only in the eastern part of the county, capping most of the hills as far west as Linn and Chamois. Farther west it was not observed. It is ten feet thick on Galloway's Prairie. About Sec. 28, Township 43, Range 7 W., it is ten feet thick."

First sandstone in Miller county.

In Mr. Meek's report on Miller county[1] he speaks of recognizing the First or Saccharoidal sandstone: "This member of the Magnesian Limestone series was only recognized on the higher country in the northern part of the county. The farthest point toward the south at which I observed it is in the northwest quarter of Sec. 2, Township 41, Range 14 W., where it crops out on a small branch of Saline creek, showing a thickness of about sixteen feet. At another place, about 2 1-2 miles further to the northwest and near Cole county line, large masses of this rock were seen on a ridge indicating a thickness of over twenty-five feet. Similar bodies of it were likewise observed on the summit of the highest part of the county in the northeast quarter of Sec. 11, Township 42, Range 14 W.; it also occurs at another place about one mile north of this outcrop, at about the same elevation."

In Morgan county.

In Morgan county Mr. Meek[2] also notes Saccharoidal sandstones: "Exposures of this sandstone were seen in almost every township north of Versailles and at a few places southeast of there, in Township 42, Range 16 W. It generally crops out on or near the more elevated portions of the county and rarely forms continuous exposures of much extent. Sometimes it thins out quite suddenly to only a few feet in thickness and in other cases swells very abruptly from 10 to 15 feet to as much as 50 or 60 feet." First sandstone is also "*recognized*" in Saline county cropping out on the Missouri river, by Mr. Shumard.[3]

On page 191 Mr. Shumard refers to the First sandstone in the following terms: "This formation appears merely as outliers of no great extent on or near the tops of the highest ridges of

[1] Report Mo. Geological Survey, 1855 to 1871. p. 110.
[2] *Ibid.*, p. 142.
[3] *Ibid.*, p. 178.

Ozark county. The descriptions you have given of it in the published report will very nearly apply to it here. It is usually a friable sandstone, its color passing from a pure white to a reddish brown. Its thickness varies from four to eighty feet." He reports fossils as being found in the localities of the First sandstone.

In Wright county, page 207, Mr. Shumard also reports First sandstone in Township 29 N., 14 W. Sections 34 and 35: "This sandstone exists on many of the higher elevations throughout the county and its presence is generally recognized by detached masses lying over the surface. These masses probably once formed a part of this formation." In Wright county,

In Phelps county, Mr. Shumard reports First sandstone as occuring as "usually of moderately fine, transparent, rather slightly cohering quartz grains, in thin or massive beds; the color varies from white to ferruginous brown, the grains of the latter variety being sometimes strongly cemented with iron."[1] In Phelps,

In Crawford county the same writer reports First sandstone as follows: "This formation is well represented, but, as far as our observations extend, it is confined almost exclusively to the highest points of the dividing ridge between the waters of the Meramec and the country lying north of this ridge. The rock occurs in massive beds, and in thin, laminated layers, which vary in compactness from soft crumbling sandstone, to almost a quartzite; its colors are snow-white, brown and red. The rock, as it appears in this county, cannot generally be distinguished from the Second sandstone, save by its stratigraphical relations, the lithological characters of the two formations being almost precisely the same."[2] In Crawford,

In Cape Girardeau county the same author, referring to the First sandstone, says: "This member of the series presents the same lithological features in Cape Girardeau as in other parts of the State."[3] In Cape Girardeau and

He also describes the First sandstone in Ste. Genevieve county. His section compiled from the observations of himself and of St. Genevieve counties.

[1] *Ibid.*, p. 235.
[2] *Ibid.*, p. 245.
[3] *Ibid.*, p. 268.

Warwick Hough, Esq., is also given in full. A copy of this section is introduced on p. 40, as Fig. 40, of this report and the following description is further copied in order to bring out clearly the method employed in the identification of these sandstones and limestones.[1]

Characteristics of First Magnesian limestone in St. Genevieve county.

"*First Magnesian Limestone.* This member in Ste. Genevieve consists usually of thin, even bedded, buff, and cream-colored silico-magnesian limestone, passing sometimes into a nearly pure dolomite. It forms for the most part smoothly rounded hills, with gentle declivities, from which strata project at intervals in long parallel lines. The surfaces of some of the layers are marked with vertical joints, intersecting each other in every direction, which have been formed from the shrinking of the strata while in a soft condition, and subsequent filling of the cracks with fine mud."

"The First Magnesian limestone forms the prevailing rock of the hills at the heads of Fourche a Polite, and North and South Gabouri, and extends northwest in a narrow belt into Jefferson county, crossing the Establishment below the mouth of the Fourche Duclos. It is also exposed on the Aux Vases below the mouth of Mill Creek, and on the Saline near the line of Perry county. Its thickness in Ste. Genevieve I have estimated at 150 feet."

Saccharoidal sandstone.

"*Saccharoidal Sandstone.* This important formation consists of white and ferruginous sandstone, occurring, usually, in massive beds. Its lithological and chemical characters in this country have been fully described by Dr. Litton, in the second Annual Report (Part II, page 85).[2] It extends southwest in a narrow strip, from half to three quarters of a mile wide, from the head branches of the Isle le Bois to the Aux Vases, which it strikes below the mouth of Mill Creek. The best exhibition of it to be found in the county are at the "White Sand Cave,"

[1] *Ibid.*, p. 298.

[2] Dr. Litton merely says that this is a remarkably white sandstone which crumbles easily upon slight pressure; that it is made up of rounded grains with little or no cementing material. It does not color by heating and probably would not stain the glass made from it. These are all the lithological characters given. F. L. N.

eight miles nearly due west of the town of Ste. Genevieve, and on Kaufman's land in T. 37, R. 8, Sec. 3. At the former locality a thickness of about twenty-five feet of the pure white variety is exposed in heavy beds. This locality furnishes the white sand so justly celebrated for the manufacture of the purer varieties of glass. Thickness from thirty to eighty feet."

"The *Second Magnesian Limestone* occupies a large area, chiefly in the central and northwestern portion of the county. If we draw a line passing southeasterly from the sources of the Isle le Bois to a point on Mill Creek, about a mile and a half above its confluence with Aux Vases, and thence extend this line to the Saline, a short distance below the mouth of North Fork, we shall have pretty nearly the line separating this formation from the Saccharoidal sandstone; west and south of this line it ranges from one to three miles, forming, like the First Magnesian, nearly rounded hills with gentle declivities."

Characteristics of Second Magnesian limestone.

"The *Second Sandstone* constitutes the surface rock over a larger portion of the country than any other formation, and it also presents a greater vertical development than we usually find in other counties of this portion of the State. It is constantly encountered on the high ridges at the sources of the Establishment, Terre Blue, Aux Vases and Saline. We find it also occupying the highlands in nearly every section in T. 36 and 37, R. 7. The rock varies in lithological character in different parts of the country, but usually appears in thin beds of white, yellow or reddish colors, and made up of moderately fine siliceous grains. Near Cozzen's Mill on the South Fork of Aux Vases, a thickness of about eighty feet is exposed, and here the rock is curiously weathered into huge conical and domeshaped masses that rise from ten to twenty feet above the surface, some of them standing quite isolated and others joined at different heights from their bases. In this vicinity the rock occurs in heavy beds, and passes from a fine-grained sandstone to a coarse gritstone containing large pebbles of milky and translucent quartz. North of this place, near Junca Creek, the sandstone is very much indurated, and sometimes passes into a conglomerate. On the Mineral Fork of the Saline it is a coarse gritstone of a dirty, gray color, and contains galena and much sulphuret of iron. The thickness of

Second sandstone.

the Second sandstone, in this part of the county, may be safely stated at 150 feet, although we have not seen a greater thickness than eighty feet exposed at any one point. Nearly the whole pine district of this county is underlaid by the Second sandstone.

acteristics of rd Magnesian estone.

"The *Third Magnesian Limestone* is principally met with in the cuts of the streams in the western and southern portions of the county. It is the prevailing rock of the North Fork of the Saline and tributaries throughout nearly their entire course. We find it also well developed on the upper part of the Establishment and its branches, and likewise in the head waters of Fourche Duclos. On all these streams it presents the usual lithological characters of the mass, frequently forming bold escarpments, with mural faces, and sometimes exposed to the height of 150 feet."

The last reference to the First sandstone is made on page 308 of this report and is mentioned under Jefferson county.

Inadequacy of Earlier Observations. Several references are also made to this series of rocks in the Geological Survey Report of 1873. The figure on p. 96, copied from Mr. Shumard's section,[1] shows the order of sequence. The fact, however, that this sequence is a compilation and not made from an actual exposure must be carefully borne in mind. In the first place the First Magnesian limestone is *recognized*, not *identified*, at the head

above se ence is in- red from arated ob- vations.

of Gabouri creek. Second, the First sandstone is *recognized* at least three miles distant at White Sand cave. Third, the Second Magnesian limestone is *recognized* in the middle of the county. Fourth, the Second sandstone is *recognized* in the western (and highest) part of the county. Fifth, the Third Magnesian is *recognized* at the head of the Aux Vases and Establishment creeks. That is, the column is made up of the various rocks

s of the Mag- sian series are at all identi- l

from observations at isolated localities covering almost the entire county. Special emphasis has been laid by the writer upon the word "recognized" since this word, or "observed," is the one universally adopted by Mr. Shumard and the other geologists in recording the results of their studies of these rocks.

[1] Report Geological Survey of Missouri, 1855-1871, op. p. 292.

They have failed to point out the data by means of which they recognized these rocks.

Prof. Swallow's first mention of the First sandstone is on page 17, Part I, of the report 1855. He there describes it in the following terms: "This formation is usually a bed of white friable sandstone, slightly tinged with red and brown which is made up of globular concretions and angular fragments of limpid quartz. It presents very imperfect strata, but somewhat more distinct lines of deposition, variously inclined to the planes of stratification. When separated at the lines of stratification or deposition, the surface presents larger globular particles of quartz and waterworn fragments of chert, apparently from the inferior limestone, while still larger fragments of decomposing chert are frequently disseminated through the whole stratum. Sometimes it becomes a pure white homogeneous mass of slightly coherent particles of silex, which very much resembles loaf sugar."

Description of First sandstone by Prof. Swallow.

The Second sandstone is recognized (*Ibid.*, p. 125) by the following characteristics: "This is usually a brown or yellowish brown fine grained sandstone, distinctly stratified in regular beds, varying from two to eighteen inches in thickness. The surfaces are often ripple-marked and micaceous. It is sometimes quite friable, though generally sufficiently indurated for building purposes. The upper part is often made up of thin strata with limpid crystals of quartz. Fragments of these strata are very abundant in the soil and on the ridges where this sandstone forms the surface rock. It sometimes becomes a pure white grained soft sandstone."

Description of Second sandstone quoted.

From the above description it will be seen that the distinctions are purely lithological. Even if lithological distinctions had any great force in determining geological horizons, it is apparent that not a single characteristic is given which might not with perfect propriety be applied to either bed. In fact there is not an exclusive characteristic given.

The distinctions are wholly lithological.

The fact of the existence of three distinct sandstones could be well established for a given locality if they were found actually superimposed with their separating beds of limestone. But this has not, with a single very doubtful exception, been done;

The existence of these sandstones not established by observed superposition.

this is in the so-called artesian well at St. Louis. This well was put down with a churn drill so only triturated fragments of rock were taken out, and from these data the section was constructed.

Means Available for Correlation. By far the most conclusive evidence in the establishment of horizons is the occurrence of characteristic fossils. Unfortunately, in this respect, the rocks of the Ozark series in the Ozark Uplift are very deficient. This is by no means due to a lack of life in the Cambrian seas at the time these rocks were deposited, for certain localities show the former presence of abundant fauna, but simply that, in the greater part of the rocks, all recognizable traces of life have been destroyed. The problem of establishing the identity of two or more outcrops of sandstone or limestone thus becomes exceedingly difficult. With these ready means of identification almost wholly wanting the work of correlation, even under ordinary circumstances, is an extremely difficult one. The river systems of the Ozarks, however, have done much to obviate this difficulty. As has already been pointed out these streams rising, as they do, in the higher plateau cut deeper and deeper into the rocks of the Uplift as they make their way down its slopes. Bluffs, showing every successive stratum, vary in height from twenty-five feet or less at the source to over five hundred feet near the mouth. These bluffs succeed each other so frequently that the varying phases of each stratum can be traced from one to the other. In this way also, a given bed or stratum can be followed almost from its inception to its disappearance.

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rrelation.

Sections Along the Big Piney, Gasconade and Current Rivers. In prosecuting the study of iron ore deposits of the State it was thought advisable to determine, if possible, whether or not the specular ores of the sandstone region and the limonite ores of the Uplift followed any particular stratum in the Magnesian series of rocks. With this end in view a trip was made by boat from the headwaters of the Big Piney river, near Cabool, to its junction with the Gasconade river and thence to the mouth of the Gasconade at Gasconade City. This section gives a view of the rocks on the northwestern slope of the Uplift. The southeastern slope was studied by following the Current river from Riverside, in Shannon county, to Doniphan, in Ripley county. It will thus

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arks.

—Contact

View in railway cut at Cedar Gap, showing the contact between the Chouteau limestone and the underlying Ozark beds. *From a photograph.*

be seen that an entire section has been made across the Ozark Uplift. The sections thus made are given on Plates III. and IV., inserted opposite page 106.

At Cabool there is but very little else than sandstone, overlain by clay with more or less chert. No solid limestone is seen. Thirty miles to the west, on the line of the Kansas City, Fort Scott and Memphis railway, near Cedar Gap, the limestone is very heavy. In a railroad cut two miles east of Cedar Gap there is a beautiful exposure of a contact between the Ozark limestones and the Kinderhook, and the chert in the clays overlying the Chouteau is highly fossiliferous. The Magnesian limestone beneath the line of contact, on the slope of the hill, was followed to the south of the railroad track for nearly one mile. Frequent exposures of rock on the steep side hill made it possible to note any variation in the rocks themselves. Through a vertical distance of 270 feet the following changes were noted (see Plate III.): —

Contact between Lower Carboniferous and Magnesian.

Chouteau limestone	20 feet
Magnesian limestone	40 feet
Sandstone	6 feet
Limestone	54 feet
Sandstone	1 foot
Limestone	49 feet
Sandstone	2 feet
Limestone	118 feet

Below this point the rocks were not to be observed continuously and no further study was made of them.

Between Cedar Gap and Cabool no detailed study of the rocks was made. Between these two stations, along the line of railroad, there is a difference in elevation of about five hundred feet. The grades along the road are very heavy. It was noted that along the road the highest points were limestone and the lowest were usually sandstone. On some of the higher points, near Cabool, limestone was noted, and sandstone at the lower points.

Limestone and sandstone observed between Cedar Gap and Cabool.

The sections in the two plates opposite next page are numbered consecutively on Plate III. from No. 1 near Cabool to No. 32 at Gasconade City, omitting numbers 27, 28 and 29. Then beginning at the head of Current river, down to Doniphan another series

of sections are given on Plate IV., and here also some of the sections numbers are omitted in the plates and are given separately in the text. The township, range and section of the sections are given only approximately since it was evidently not practicable to get them exactly without great loss of time.

ions not exactly located.

Although not continually in sight it will be assumed that the sandstone which is in sight at Cabool is the same one as is exposed at Section No. 1 of Plate III. The reasons for this assumption are that from Cabool to this section, a distance of about eight miles, the country is only gently rolling, the summits of the rolls are limestone, the hollows are sandstone. Further, the barometer stands at about the same level at the two places.

From this point down the river, a very interesting series of phenomena is shown. One very prominent fact soon makes itself very strongly felt and that is the great and sudden variability in the thickness of any given bed either of sandstone or limestone. In Section No. 1 the exact thickness of the sandstone which outcrops there is not known. There is no limestone which shows on top of the sandstone, but it is covered with a thick mantle of stratified clay, the residuum, probably, of a former limestone. This assumption is fortified by the fact that,

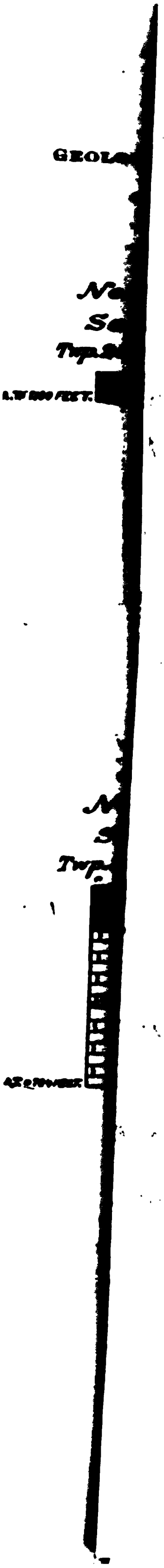
sandstones ry in thickes.

a little distance below this section, argillaceous shales begin to appear in the clay, and this, in Sec. 2, gives place to a cherty limestone. In Section No. 4 the sandstone grading insensibly into chert and cherty limestone, reaches a thickness, between two beds of limestone, of one hundred and forty feet. Again, in Section No. 3 a bed of limestone fifteen feet thick appears. In Section No. 4 it reaches an observed thickness of twenty feet and, in Section No. 5 it is one hundred and ten feet, and this almost entirely disappears in Section No. 6 and is not observed

estone forms nses in sand one and clay es.

in Section No. 7 where the solid sandstone thickens to one hundred and sixty-six feet. In Sections No. 8 and No. 10 the tendency of the limestones to form lenses in the body of the sandstone is well shown. From the facts expressed in these two sections the inference is that the limestone is a lenticular body, since, at corresponding levels in Sections No. 7 and No. 9, nothing but solid sandstone is seen.

The occurrence of great lenses of sandstone is still further



shown in Sections 27, 28 and 29 of Fig. 41. As will be seen by referring to Plate III., Section 26 shows a face of two hundred feet of pure limestone, capped by twenty feet of broken sandstone. About one mile below this section large broken blocks of ripple-marked sandstone appear in the river, broken from a bed of sandstone thirty feet thick. This sandstone is a heavily bedded, Saccharoidal rock, which can be traced for a long distance at the river level. Section 27 in the accompanying cut shows the relation of this sandstone to the overlying rock. Unfortunately the talus from the bluffs hides the rocks at the most critical point, but at A the sandstone shows out heavily bedded and very pure. At B, less than three hundred feet distant, the sandstone is more or less calcareous. The broken sand-stone on top is about twenty feet thick. One-fourth of a mile below is Section 29. The first twenty feet above the

Lenticular occurrences proved.

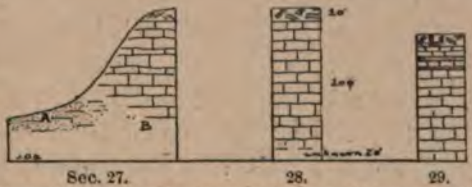


FIG. 41. Sections along the Gasconade river, showing the thinning out of the sandstone at A.

river level is covered by talus but above this is solid limestone for two hundred feet, with a cap of twenty feet of broken sandstone. Less than one mile below this point Section 29 shows a bluff two hundred feet high. In this two beds of sandstone, calcareous, and about two feet thick, show, and about one hundred and forty-eight feet of limestone.

The inference is thus unavoidable that the sandstone beds of Sections 27, 28 and 29, ripple-marked and thick as it is, is lens shaped and lies, probably, wholly enclosed by limestone. Sections 49 and 50, Plate IV., show a bed of very pure sandstone lying in limestone and probably thinning out, as is indicated in the sections. At least Section 51, three or four miles below, shows three hundred and eighty feet of pure limestone.

Sandstone of Secs. 27, 28 and 29 is lens shaped.

By further consulting the plates of sections it is noticeable that a bed of sandstone generally occupies the crests of the sections.

Sandstone is observed capping bluffs continually.

This fact is very much more striking in the field than in the sections, for there is an almost continuous wall on one or the other side of the streams. Even on the bluffs where no sandstone is shown, if the hill is followed back from the river for distances varying from one to one-half of a mile, this rock will generally be found, through perhaps only in broken blocks. It is thus probable that this bedded sandstone, which is observed at Cabool, is continuous to Gasconade City, in a bed of varying thickness as well as from Riverside to Doniphan.

Sandstone caps sometimes broken or disturbed by undermining.

This sandstone, if in broken blocks, usually lies a little below the level of the more undisturbed or bedded sandstone, but in such a position as to be readily referred to the unbroken or less disturbed beds. If it occurs in unbroken beds or layers, the hill or divide can be followed for miles on nearly the same level, and winding, as the streams between which it lies, the ridge comes sharply to the river in the form of a steep bluff; or it swings back as a more or less steeply sloped hill. The difference between this sandstone and those previously described may be summed up as follows: While the sandstones first described as cropping out in the river bluffs come in gradually, thicken and gradually disappear, this sandstone occupies a constant position with relation to the limestone rock with which it occurs.

The formation of limestone and chert breccia.

Disturbances of Strata. In some cases the appearance of sandstone on a low bluff is not attributable to a thickening of the bed at the expense of the limestone. Its broken and disturbed appearance, the crushed appearance of the limestone, together with sudden aud rather steep dips seem to make it probable that the rocks have been undermined and caused to fall by the etching away of beds of limestone. The facts which lead to such a conclusion are very evident. In many of the bluffs the limestone beds are completely honey-combed. The cells vary in size from an inch in diameter to large openings which may properly be called caves. One can very easily imagine this honey-combing to be carried on to such an extent that the weakened rock, no longer able to support the superincumbent mass, would be crushed thus allowing the whole mass to settle. One of two things would happen. First, the entire soluble part, water now having freer access, would be removed, thus allowing

more settling; or, if the limestone was argillaceous, a parting bed of clay would be left. Second, the crushed beds might be recemented and thus present the rather paradoxical phenomenon of a bed of limestone breccia between two beds of solid limestone.

Direct evidences of settling are so numerous that only a few examples will be given. About two miles above Myer's mill on the Big Piney the limestones dip toward each other at an angle of from 15° to 20°. The beds are so massive and otherwise look so undisturbed as to suggest a synclinal trough. A large spring at the lowest point of the synclinal, however, explains their position. This spring, it can be seen, has undermined these rocks and they have fallen in as described.

Direct evidences of undermining.

Nearly every one of the great springs of this region shows the rocks dipping towards the cave from which it emerges. Further, also, as will be explained in the chapter on "Specular Ores of the Sandstone Region," the sandstones all dip towards the ore deposit.

As an evidence of undermining and removal of the soluble limestone it may be pointed out that mining operations show that these sandstone beds are, in most instances, underlain by beds of clay, inter-stratified with slaty and cherty layers. This fact is perfectly illustrated at the Cherry Valley iron mine. In general the shrinkage of the mass of rocks of the Uplift by the loss of soluble carbonate of lime is widely recognizable. Beds of lime and chert breccia are also frequently met, and all seem to point to the conclusion suggested above. It will thus be seen that the position of the sandstone on limestone bluffs of varying altitudes may at times be due to undermining and settling as well as at others to the thickening and thinning of the beds themselves. By carrying out the ideas suggested above, in regard to thickening and thinning we can easily imagine that a bed of sandstone, very thick at one place, may be subdivided by the coming in of a limestone, or may thin out, in such a manner as to suggest a series of great beds of sandstone rather than one practically continuous bed. In fact the sections made along the rivers show this very clearly. It is only by carefu observation of a given sandstone bed, from bluff to bluff, noting

Thick beds of sandstone break up into "stringers."

changes in thickness and signs of undermining, that the bed can be certainly identified and followed.

Paleontology of the Region. Another fact supporting the existence of the continuous bed of sandstone, already referred to, is the persistent occurrence of a distinct fossil stratum always occurring in the same well recognized relation to the sandstone. This fossil bed is found, usually, within twenty feet of the sandstone and is, almost without exception, a calcareous chert. The proportion of lime to chert varies from an almost pure chert, though distinctly laminated, to an almost pure limestone. The fossils are, however, almost without exception, siliceous casts.

A distinct fossil bed is traceable.

The distribution of the principal localities may be seen by referring to the marginal maps accompanying the plates of sections, and to the sections themselves. Comparatively few of the fossil localities have, however, been located, only the better ones are shown of the maps, for they may be found in nearly every bluff. At the request of the writer, Prof. R. R. Rowley, assistant in paleontology for the Survey, visited some of the localities and the following fossils were identified by him. At Hazleton, township 33 N., 10 W., Sec. 35, on Big Piney river, he found the following specimens: *Orthoceras primigenium* (?), *Ophileta complanata*, *Straparollus minnesotensis*, *Murchisonia melaniaformis*, *Pleurotomaria sp.* (?), *Orthis sp.* (?) small, *Leptæna sp.* (?) and glabella of a trilobite. Near Riverside on Current river, township 31 N., 6 W., section 10, he found the following species: *Straparollus sp.* (?), *Ophileta complanata*, *Orthorceras primigenium* (?), *Holopœa sp.* (?) small specimen. Near Akers P. O., a few miles below, he found *Orthoceras primigenium*, *Straparollus sp.* (?), *Raphistoma sp.* (?), *Ophileta complanata*, *Pleurotomaria sp.* (?), *Murchisonia melaniaformis*. There are other localities in which fossils have been found, both by the writer and others, which seem very

Fossils sufficient to correlate separated beds.

clearly to point to the correlation of widely separated outcrops to a synchronous horizon. At the Cherry Valley iron mine, more fully described in the chapter on "Specular Ores in the Sandstone Region," a belt of fossiliferous rocks, surrounding the bank on the east, north and west sides, has been found. This fossil layer is under the sandstone, which shows plainly at the

mine, and over the limestone, which crops out in heavy beds under the ore bank. The fossils are found in a decomposed chert, some in fresh flinty chert, embedded in a clay, referred to before as a residuum from limestone. Here Prof. Rowley recognizes; *Straparollus sp.* (?), *Orphileta complanata*, *Orthis sp.* (?), *Cyrtolites sp.* (?).

In Wayne, Carter, Oregon, Howell and Taney counties the writer has frequently found these fossils in chert. The only evidence that they came from under the sandstone is that they have never been found by the writer on top of the sandstone in the cherty clay, though search has often been made. The conclusion is, then, that the sandstones found in these widely separated localities belong to the same horizon.

No Magnesian fossils found on top of the Second sandstone.

Mr. Shumard reports fossils from the following localities:[1] *Orthoceratite*, Maries county; *Straparollus* and *Chemnitzia*, Ozark county; *Straparollus bigranosus*, *Chemnitzia*, pygidium of *Arionellus* (?) *Missouriensis* from Wright county. The above are affirmed by Mr. Shumard to be from the First sandstone. He, however, gives no reason for calling the localities First sandstone, save on the lithological grounds already pointed out. The fauna is too poorly represented to furnish grounds for separation of the First sandstone by means of fossils, and the fossils given may, with equal propriety, be considered as correlating these localities with the so-called Second sandstone rather than as establishing the First sandstone on paleontological evidence.

Fauna not sufficient to differentiate First and Second sandstone.

In Miller county, under the so-called Second sandstone, Mr. Shumard finds, "*Euomphalus* and some *Gasteropoda*." In Ozark county he finds the following fossils in Second Magnesian limestone, and, consequently, *over* the so-called Second sandstone: *Murchisonia melaniaformis*, *Melia*, *Orthoceras primigenium* *Lituites complanata*, *Chemnitzia resticula*, *C. ozarkensis*, *Murchisonia carinifera*, *Straparollus vulvataformis*, *S. bigranosus*, *Raphistoma grandis*, *R. subplana* and *Arionellus* (?) *Missouriensis*. Also trilobites and gasteropods which are

[1] Report Geological Survey of Missouri, 1855-1871, pp. 10, 192, 208, in the chapters on Miller, Ozark, Wright and Pulaski counties.

undetermined. In the Second sandstone (so-called) he finds *Raphistoma* and *Straparollus acuto-carinatus*.

Especial attention is here asked to the following facts. In the first place that the individual strata making up the Ozark series have not been sufficiently well defined, by the writer above quoted, for their ready recognition to be beyond question. It would then follow that the statement that the above fossils were found in the Second Magnesian limestone and thus over the Second sandstone and under the First sandstone, will not hold in the face of evidence to the contrary. There is such evidence and it is as follows: These same fossils have been found by the writer, and identified by Prof. Rowley, from positions *under* the sandstone which Mr. Shumard has "recognized" or referred to as Second sandstone. The localities found by the writer bear a very constant relation to this Second sandstone of Shumard. Even if the fossils described by the writer are not of themselves sufficient to establish firmly a fixed horizon, would it not at least, seem simpler and more logical to hold that the last fossil locality described by Mr. Shumard goes rather to establish the fact that the supposed First sandstone is nothing but the so-called Second sandstone and that the supposed Second Magnesian limestone lies *under* the Second sandstone and not on top? In Wright and Jefferson counties Mr. Shumard describes fossils, similar to the above, as occurring in the Second Magnesian limestone (thus under the First sandstone). In view of the reasons given, the writer holds that these fossils go rather to prove the continuous extension of the so-called Second sandstone than the existence of the Second Magnesian limestone.

s described umard go tablish a inuous stone, not and Sec-

The Indentity of a First Sandstone Questionable. There are one or two facts which lead one to further question very seriously whether the existence of a First sandstone has been established on facts strong enough to warrant the retention of the term. In the report before referred to, Prof. G. C. Broadhead has recognized the First sandstone in Osage county, in the following places.[1] Under the head of F. *u.*, Saccharoidal sandstone, he

[1] Report Geological Survey of Missouri, 1855-1871, p. 26.

says: "This formation is found only in the eastern part of the county, capping most of the hills as far west as Linn and Chamois. Farther west it was not observed. It is ten feet thick in Galloway's Prairie and the head of Third Creek, but it is not again seen in any large mass until we cross the Gasconade and reach the interior of T. 43 N., R. 7 W. About Section 28, 43 N., 7 W., it is ten feet thick. It crops out near the summit of the ridges, between Bailey's creek and the Gasconade river. It is generally a white, soft, pure sandstone." By referring to Plate III, Section 32, it will be seen that the section shows thirty feet of sandstone at the summit of the bluff. No fossils were found under this sandstone but this is the same sandstone which has been followed from the head of the Big Piney near Cabool, capping the summits of nearly every bluff to this point at the mouth of the Gasconade river, in some places it is one hundred and ninety feet thick. This particular section is in Gasconade county, but it is only just across the Gasconade river from Osage county. Further, Chamois, a point where Prof. Broadhead recognized the First sandstone, is *lower* than the point where the Second sandstone is represented in Section 32, Plate III. This bluff is three hundred and five feet above the level of the Gasconade river. The bluff at Chamois is not so high by at least one hundred feet. In Township 43 N., 7 W., Section 28, First sandstone is again recognized by Prof. Broadhead. Section No. 25, Plate I., was made by the writer only three miles distant and southeast from the place where Prof. Broadhead recognized First sandstone. The writer's note on this locality as evidencing a sinking of the sandstone by leaching of the limestone, is as follows: The chert layers in this bluff, as in many others, are all crushed or brecciated, and the interstices are filled with sand and limestone and recemented. The sandstones on the top of the bluff, although in large masses, are disturbed, showing that they have been undermined and have settled without having actually been broken. Fossils, or rather fragments of fossils, were found in the chert. Again, attention is called to the fact that this sandstone has been traced continuously along this stream and the Big Piney, and that this outcrop evidently belongs to the same bed. It seems very probable, there-

Farther evidence of the identity of First and Second sandstone.

Sandstone disturbed.

fore, that the localities recognized by Prof. Broadhead and the present writer belong to the same horizon. If this be so there can be no doubt but that, in the great central area of the Uplift there is practically but one sandstone, and that sandstone is the one which has, up to the present time, been called the Second sandstone.

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Nomenclature. One word more must be added. Even should we wish to retain the names of First, Second and Third sandstone, there is yet an embarrassing question to answer. The older geologists acknowledge that these beds thicken and thin within wide limits. In Section No. 32, Plate III., there are thin beds of sandstone which are not given on account of their thinness. In that section alone, if we grant that there is a First sandstone, we have not three sandstones, but five, not counting the so-called Third sandstone which lies yet lower. In Section No. 8, on Big Piney, there are at least five sandstones, allowing for the First sandstone which has been swept away and for the Third sandstone which lies below. In Section 23, on the Gasconade, allowance must be made for at least six beds of sandstone. There seems to be, therefore, no valid reason for stopping at three sandstones, but if numerical distinctions are to rule, there should be no reason why the beds should not be denominated by numbers from one to six at least. It will, at present, at least, be no valid objection to point out that many of these beds are thin. All are not so, some are thirty feet thick, and are not to be distinguished lithologically from what has been called First, Second, etc. Further, thin beds may thicken at other points. It is very evident, however, that such a proposition is a *reductio ad absurdem*, and, if introduced, would lead to endless confusion. It is firmly believed by the writer that the old terms First, Second, etc., as applied to the sandstones and limestones, should be set aside as no longer useful but, on the contrary, as serious obstacles in the way of working out the stratigraphy of the Ozark Uplift.

...re not ...but six ...tones.

...irst, ...d, etc., ...tones and ...ones ...l be ...oned.

In view of the facts above pointed out it is suggested that the name *Roubidoux* sandstone be applied to the rock above described as overspreading the Ozark region from Cabool to Gasconde City and from Salem to Doniphan. This embraces much, if not all,

of what has been called Second sandstone, and will undoubtedly include the areas of so-called First sandstone as well. Further, it is proposed that the name *Gasconade* limestone be applied to the great series of limestone beds, interstratified with thin beds of sandstone, which underlie the Roubidoux sandstone. It is firmly believed that enough occurrences have been examined to at least include all of the great outcrops of sandstone properly lying within the Ozark Uplift in the Roubidoux sandstone, and, if further work proves the correctness of the writer's belief that the heavy beds of sandstone at Pacific and Crystal City, hitherto known as First sandstone, are but an extension of the Second sandstone, the term Roubidoux can be extended to these also. From the fossils found in the Roubidoux sandstone, as well as from the fact of the close relationship of the underlying limestone, the Gasconade limestone will be as easily identified as is the Roubidoux sandstone. These terms are offered, at least for provisional use, without wishing to cast the slightest imputation upon the work of Swallow, Shumard, Broadhead and others of the earlier geologists; for the present writer can only consider himself as carrying a little farther the work so ably inaugurated by these men and especially by Prof. Broadhead.

Area embrace[d] the Roubido[ux] sandstone a[nd] Gasconade li[me]stone.

CHAPTER VI.

THE SPECULAR ORE OF THE SANDSTONE REGION.

INTRODUCTION — SIMMONS MOUNTAIN MINE — THE CHERRY VALLEY MINES — THE COMPOSITION OF THE SPECULAR ORES OF THE SANDSTONE REGION — THE ORIGIN OF THE ORES — PROSPECTS FOR THE FUTURE — CONCLUSIONS.

INTRODUCTION.

General Distribution. The district in which the specular ores in sandstone are found has been designated as the "Central Region" by Dr. Adolph Schmidt in his report of 1872.

nces of lar ore.

There are eight counties, Franklin, Crawford, Maries, Phelps, Pulaski, Dent, Texas and Shannon, in which these ores have been found most abundantly. Crawford, Dent and Phelps counties, though, have yielded the principal amount of ore. The fact that, so far, the other counties named have produced but little ore does not necessarily mean that there is but little ore in them, but simply that circumstances have not been favorable for working and thus there has been lacking a stimulus for exploration.

ance of the au region.

The district occupies the high position in the Ozark Uplift which has been described in the preceding chapter as the plateau region.[1] Its topography is essentially different from that of the country to the north and south. It is hilly, but the ravines which cut the surface of the ground are not so deep as those of the sections just referred to. As one leaves this region and approaches the cañon or gorge region the deposits of specular

[1] During my first visits to the Ozarks the term "plateau" suggested itself to me as being a peculiarly appropriate one as applied to certain counties south of the Missouri river. It was not till considerably later that I found that this term had already been applied to it by Prof. Broadhead, and I take pleasure in referring it to him and acknowledging to him my indebtedness for this, as well as other assistance gained through his reports.

ore grow fewer in number and less valuable as commercial sources of iron ores, and the facts support the idea, later advanced, that steadily, as time goes on, these deposits are gradually being removed, to be redeposited on the lower slopes in the form of workable deposits of limonite.

The rainfall c ried away b underground drainage.

Here the Meramec, Current and Black rivers practically rise. The streams at this point are usually small and intermittent, but there is no lack of rainfall in this belt, and one is, hence, driven to the conclusion that the greater part of the water finds its way to the streams which feed these rivers through underground channels, to emerge in the form of springs. Numerous springs, some of them of great size, are abundant.

Specular ores limonites o in the same logical hori

Geological Horizon of the Ores. Geologically these iron ores are associated with rocks of the same formations as the limonites, but in different beds. The distinction, however, must be sharply borne in mind, that the conditions which produced the specular iron ores in the sandstones have long been extinct in this region; while, in whatever age the principal deposits of the limonites were formed, the causes which produced them then may be acting now. It is probable then that these two varieties of ore, seemingly so closely associated, may yet be widely separated as to time. Still further, it is probable that the specular ores were from their nature deposited in a fixed geological period, while the limonites were either derived from the specular iron ores by hydration, by solution and by redeposition, or they were derived directly from the rocks with which they are now associated. The reasons for the above statements will appear later.

Specular ores found in the sandstone region.

It is a striking fact that the specular ores are found almost exclusively with the Roubidoux or Second sandstone[1] (as it was called), of the Ozark series; while equally, with few exceptions, the limonites are found in connection with limestone. The low, broad-topped hills of this region are capped by this Roubidoux sandstone, and it is upon these hills that the deposits of specular ores are found. In the adjoining ravines it frequently happens that streams have cut through this cap of sand-

[1] Second Annual Report of the Geological Survey of Missouri, 1855, Part I, p. 125.

stone and the underlying Gasconade limestone is shown.[1] Here, occasionally, a bed of specular ore is thus cut through and the underlying limestone is partially covered with rounded boulders of specular ore, all the softer parts of the bed having been carried away.

Character of the Ores and Associated Minerals. The general appearance of the specular ore in the sandstone is wholly different from that in the porphyry. While the porphyry ore is usually coarsely crystalline, the sandstone ore is fine grained and compact. Crystals of hematite are rare in both localities; but, when crystals of hematite are found in the sandstone region, they are, to the naked eye, but shapeless scales. As to purity, the ores of the sandstone region are often highly siliceous, and in this respect they closely resemble the limonites. There are large deposits of what would at first sight appear to be a fine ore. Careful inspection, however, shows the deposit to be a highly ferruginous sandstone. This, analysis shows, carries fifty per cent. of silica, the remainder being principally specular iron. There are large areas of this material in which are found only very little workable ore. To the unaided eye this sandstone is very deceptive on account of its being very fresh and tough, and, when broken, the clear grains of quartz sparkle like the crystalline faces of the pure ore. Sulphur is found quite abundantly in a few mines; but generally it is in very small quantities except at the bottom of the deposit. At the Anaconda mine, near Dry Branch, on the St. Louis and San Francisco Railway, large masses of sulphide of iron are found, having a beautiful feather structure. The outside of these blocks or boulders are covered with a thin skin of limonite. The presence of the sulphur does not seem to interfere with the value of the ore deposit, since it is so concentrated, when it occurs, that it can be readily cobbed out and thrown aside. At the Cherry Valley bank no sulphide of iron was found until very nearly the bottom of the present large opening was reached. A single test pit sunk in the floor of the opening apparently showed that the

[1] This peculiar structure is typically seen along the line of the Salem and Little Rock railroad, from Cuba to Millard furnace; and also along the banks of the Meramec river.

View of Simmons Mountain mine, looking southwest, showing the broken outcrop of sandstone, cemented with iron, dipping northeast.

Reproduced from a photograph.

whole of the deposit was underlain by sulphide of iron disseminated in clay. At numerous other banks, now worked, search was made for this sulphide, but it was not found. Masses of porous limonite were found, however, which had a feather structure. It was concluded that, if sulphide of iron had existed here, the open nature of the deposit had allowed the pyrite to change to limonite. The mine at Simmons mountain has been nearly worked out, and but little sulphide of iron has been found.

Pyrites changed to limonite.

Chert Associated with the Ore. Aside from the grains of sand in the ferruginous sandstone or siliceous iron ore, whichever it is proper to call the deposits before referred to, silica exists in the best ore banks in two other very distinct and characteristic forms. Both chert and jasper are found abundantly, though neither is found in such a manner as to add to the difficulty of selecting the ore, for both occur in regular bands or benches and so can easily be cast aside. The chert found in these mines is almost without exception oölitic. This is not peculiar to the specular iron ore, for it is found quite abundantly throughout the Ozark mountains, but it may serve to throw some light on the origin of these ores, as will be referred to later on. This oölitic structure is not confined to the chert alone but is found in a part of the sandstone as well. It is found more particularly and in the greatest abundance, in the sandstone which is nearest the iron ores. There is every gradation from specimens consisting of grains of sand which are surrounded by the thinnest spherical shell, to instances where the entire mass has been reduced to a nearly amorphous form of silica. Even in the chert itself there are many cases where there are decided traces of what appear to be remnants of grains of sand surrounded by concentric spherical rings, these are sometimes flattened or dented as if by crowding, the one against the other. The chert in many places is broken and the interstices filled with specular ore. At Simmons mountain, especially, this broken chert seems to occupy a regular position relatively to the ore as is exhibited in Plate V., opposite this page. It presents nearly a solid wall about ten feet high on the northern side of the mine and is found in layers dipping slightly towards the main ore body on the western side. It has

Chert and sand in the ores.

The chert is broken and filled with iron.

also been encountered in the drifts which have been worked out in the lower part of the mine. From this it would seem correct to infer that this layer of chert at one time extended across the space occupied now by the main ore body and had fallen to its present position through the etching away of the underlying limestone. From the fact that the ore, as specular hematite, fills the broken spaces, it is to be inferred that this falling in was either previous to the deposition of iron, or at least contemporaneous with it. This peculiar attitude of the broken chert is also found at the Cherry Valley bank, and, so far as can be seen, under similar conditions. Broken chert with specular iron filling interstices is also found at the Plank mine, Hawkins and Meramec banks. There is also much chert that is almost wholly amorphous and appears more like concretions. These are common to the limestones, sandstones and are also found in the mines or banks, both of specular and limonite ores.

'chert ally in- l across ace.

Relations of Sandstones and Ores. In regard to the relation of the sandstones of this region to the deposits of specular ore, there is one very striking and persistent fact. The sandstones in the immediate vicinity of the ore deposits are not horizontal, as is the general rule for them, but they are bent and broken, and they usually dip towards the mine or ore deposit. The deposit at the Meramec bank seems to present an exception to this rule, but it is only to this extent, that the greater part of the sandstone appears to dip away from the deposit. Dr. Schmidt in referring to this fact, and to the shape of the ore bodies,[1] uses the following words: "These deposits of specular ore have generally a lenticular shape, with either circular or elliptical outlines. They are frequently found in an inclined position, in which case they usually dip with the slope of the hill. Sometimes the ore is cut off abruptly at the outskirts, by nearly vertical walls, consisting of nearly vertical layers of clay, chert and sandstone. In this case, these deposits appear like large, round, somewhat lenticular pockets in the sandstone, clad with layers of clay and chert, and filled with specular ore, which is often more or less altered into soft red

dstones oken and l.

[1] Report of the Geological Survey of Missouri, 1872, Part I, p. 125.

hematite. The thickness of these deposits is, on the average, one-fifth to one-sixth of their average diameter. The ore is directly surrounded and underlaid by formerly continuous, but now broken and disconnected, strata of gray or green chert or flint, sometimes mixed with a fine siliceous, white clay, or with red loam. Below these chert layers we find alternating strata of chert, sandstone, and of chert breccia, cemented by sandstone, sometimes continuous, but mostly broken. Below these are the regular strata of the Second sandstone, running parallel with the above and forming a circular or elliptic depression, in which the ore body lies. At the outskirts of this depression, where the sandstone strata suddenly change their nearly horizontal position to curve downward and to run beneath the ore deposit, the upper strata are frequently broken off, and form an annular outcrop around the deposit." The ore bodi are lenticul

"All these various rocks surrounding and underlying the specular ore deposits, have in some cases their original and natural color and appearance, while in other cases they are ferruginous, or colored and impregnated by iron ore, whereby the sandstone turns brown or black, and glittering with numerous fine ore crystals throughout its mass, while the chert is colored green or red, and the clay or loam is transformed into a reddish brown, sometimes pretty hard, ferruginous clay rock." Adjacent roci are usually ruginous.

* * * * * * *

"The above description gives us the following two series of successive layers of rocks lying above, in, and under the specular ore deposits in sandstone:

Section or ore deposit.

1. *Sandy and cherty soil.*
2. Sandstone with solid chert layers, same impregnated with iron ore, sandstone, loam and chert, broken and mixed. Solid chert. Broken chert and clay. } Cherty detritus and Limonite.
3. *Soft Red Hematite.*
4. *Hard Specular Ore.*
5. White clay or red loam. } Ferruginous clay rock.

6. Clay and broken chert. } Ferruginous breccia.

7. Broken sandstone and chert with layers of solid chert. } Sandstone impregnated or colored by iron ore.

8. *Second Lower Silurian Sandstone.*[1]

"Not all these strata are equally and invariably represented in all the deposits."

The above quotation is given at length since it agrees with the writer's own observations, except as to the bottom rock of the deposits. These deposits surely rest ultimately on a limestone or clay.

There is no positive knowledge of the immediate wall rock.

With the conclusions which Dr. Schmidt arrives at there is not the same accord. So far as is positively known there is no positive record as to what is or is not the real rock upon which the specular iron ores rest. The method which has been pursued by the companies mining the ores has been to follow the ore whenever found workable, and work is abandoned in any direction when the ore becomes too lean for smelting or rock of any kind is encountered. Thus, no definite knowledge has been gained. The sandstones curve or dip towards the ore deposits, and the deposits themselves are bedded and these beds or layers are warped and curved usually in a greater degree than in the sandstone; but the writer has not yet seen a deposit that has been proved to rest upon broken or bent beds of sandstone; but, on the contrary, all seem to show that the ores rest on the limestone floor of a former cavity. This cave was, on the floor, covered with clay and chert, a residuum of the limestone from which the cave was etched.

In support of the conclusions expressed above and in illustration of the character of the specular ore deposits a description of a few of the more prominent mines will now be given.

[1] Sandstone does not underlie deposits of specular ore, but, as seen at the Cherry Valley bank the ore is underlain by clay and decomposed chert, evidently the residue of the limestone which formerly occupied the place which the ore body now fills. Limestone forms the bounding walls for fifty feet at least above the top of the body. F. L. N.

SIMMONS MOUNTAIN MINE.

Among the iron ore deposits of this district the Simmons mountain bank is probably the one that is best known. This bank was opened some time previous to 1872, and is working to-day. Thus it has a continuous history of over twenty years.

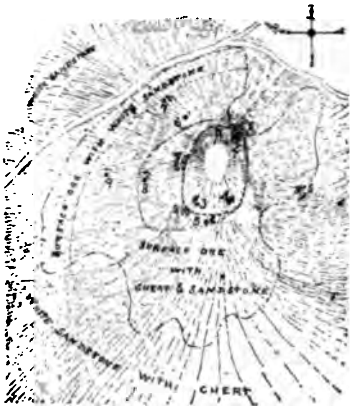


FIG. 42. Simmons Mountain in 1872.
- - - *Limit of solid ore, covering an area 500 by 400 ft.*
..... *Limit of other rocks.*
S *Outcrop of sandstone.*

The accompanying Fig. 42, shows the mountain as it appeared before the opening of the mine. The figure and the description are taken from Dr. Schmidt's Report on the "Iron Ores of Missouri" for 1872. Other figures show the structure of the mine to-day after years of working. Dr. Schmidt's description of the mine before it was opened will be interesting to compare with the appearance of the same mine to-day. On p. 136 he says: — Simmons mountain before opening.

Description by Dr. Adolph Schmidt. "Fig. 42 is a view of Simmons Mountain, which is a nearly isolated hill about ninety feet high above the plateau south of Salem, on which it is situated, and covering over thirty acres of ground."

"The main body of the hill seems to be composed of Second Sandstone, which is found in pieces on the surface, and has been uncovered by digging at the foot of the northwestern slope, close to the road. The sandstone on the surface is mixed with pieces of chert on the southern and southwestern sides near the base. Higher up it is mixed with specular surface ore, which extends over a very large district, increasing in frequency and size towards the summit." Dr. Schmidt describes Simmons mountain.

"Some of the surface ore on the slopes is altered into a fine and pure limonite (brown hematite) but most of it is specular. The latter occurs in boulders several feet in diameter. The

following topographical sketch (Fig. 42) will give a better idea of the surface geology."

outcrop was elliptical.

"We here notice, in addition to the occurrences just described, an elliptic district about 400 feet wide and 500 feet long, enclosing the summit and being very thickly covered with surface ore. This is the position and extent of the original deposit. As may be seen on the sketch, it is surrounded by outcrops of sandstone (S) which are especially distinct on the north and west sides, and are ferruginous in several places. On the east side some outcrops of sandstone are found lower down on the slope. The dip of the sandstone cannot now be distinctly recognized, but this rock will undoubtedly be found to form a large elliptic pocket filled with ore. Inside of the upper sandstone outcrops, the surface boulders are of enormous size, evidently outcrops of an immense body of massive ore. Wherever the soil is removed between these boulders ore is found immediately below it."

ace ore was ich exposed.

"Outside of this district, the surface ore although very large in places and very plentiful, must be considered as broken off from the main deposit and thrown or washed down the hill. This ore may have been at first imbedded in large masses of detritus of sandstone which was broken off simultaneously with the ore. Afterward this ore was concentrated on the surface by the slow but unavoidable and merciless action of rain water which mechanically destroyed and removed the light sandy materials surrounding and underlying the ore, while the ore itself, being too heavy to be carried off by such action, remained in place. The outside surface ore is, therefore, not indicative of the existence of large bodies of ore below it."

"These views have been fully verified by a number of shafts which have lately been sunk on the Simmons Mountain, and which on our sketch are marked by the numbers 1 to 9. The shafts 5, 6, 7, 8 and 9, which are outside the elliptic district, disclosed 15 to 25 feet of loose sandy detritus, and finally struck the solid sandstone. Shafts 5 and 6 which are nearest to the deposit, meet with more clayish materials, and streaks and masses of white clay and chert, which are so frequently found in close proximity to such deposits. The shafts 1, 2, 3 and 4 although sunk quite near the limits of the deposit but inside of

FIG. 1.

View in Simmons Mountain mine, showing south dipping brecciated sandstone which forms the north wall of the mine. (See p. 127.)

From a photograph.

FIG. 2.

View in Cherry Valley mine, showing sandstone, with underlying cherty clay dipping southeast towards the mine in background. (See p. 130.)

From a photograph.

them, went through 25 to 30 feet of solid specular ore without making the foot walls. I was lately informed that since my last visit, one of these shafts has struck the clay at a depth of a little less than 30 feet. This is not at all astonishing on account of the proximity of the shafts to the limits of the pocket. The fact that none of these shafts has reached the clay at a less depth, proves that the walls of the pocket are nearly vertical, and points to a great thickness of the ore in the central portion of the deposit. At the foot of the Simmons Mountain and to the north of it, a well has been sunk which is marked in Fig. 42. This well is over 60 feet deep. It passed through 8 to 10 feet of soil and loose sandy material; 6 to 7 feet of sandstone in broken layers; 15 to 18 feet of red sandy loam; 6 feet of chert, in thick, broken layers, 6 to 8 feet of red, sandy loan; 3 to 4 feet of chert in broken layers and 14 feet of chert mixed with clay."

Test pits prove its shape.

Present Conditions. The above description is quoted in full for it gives what is now impossible to get otherwise, a description of this noted mine before it was opened. At present it is nearly exhausted and the notes made of the mine in the fall of 1891 are given as well as the photographs taken at the same time. The elliptical shape of the ore body as marked out on the surface by Dr. Schmidt (see Fig. 42) was very well preserved as the mine grew in depth until a depth of about 15 to 20 feet was reached. Then from all sides of this opening the foot wall ran towards a common center, at an angle of a little over 30°. At present the lowest point of the mine is about two hundred feet below the original highest point of the hill. The general shape of the ore body is about that of an inverted elliptical cone; the two axes being respectively five hundred and four hundred feet.

Present workings prove Dr. Schmidt's assumption.

What Dr. Schmidt recorded as probable, the working out of the ore body has shown to be true. Fig. 1 of Plate VI., opposite this page, shows the northern wall of the mine. This wall is vertical, as the plate shows, is about twenty feet high and is composed almost wholly of cherty oölitic sandstone. The sandstone is not solid but looks more like a breccia with the interstices filled with specular ore. The whole mass is deeply stained

North wall of cherty, oölitic sandstone.

with iron. Going over the surface of this bluff, towards the north, the color of the sandstone changes to the ordinary light color characteristic of the sandstones of this region. The ore came sharply up against this wall and there stopped abruptly. This structure continued almost entirely across the northern end of the mine. Towards the east (the right-hand side of the plate), the sandstone grows more shaly in structure and dips steeply towards the center of the mine. This continues growing more and more shaly, and has a steep dip towards the center, along the entire eastern wall of the pit.

tone sur- ds the ore on three s.

The southern wall, into which the sandstone has gradually passed, is almost wholly clay with irregular layers of chert containing numerous fine nodules of specular ore and occasional large ones weighing one hundred pounds or more. The ore is not abundant enough though to pay for washing, as is the case at another point.

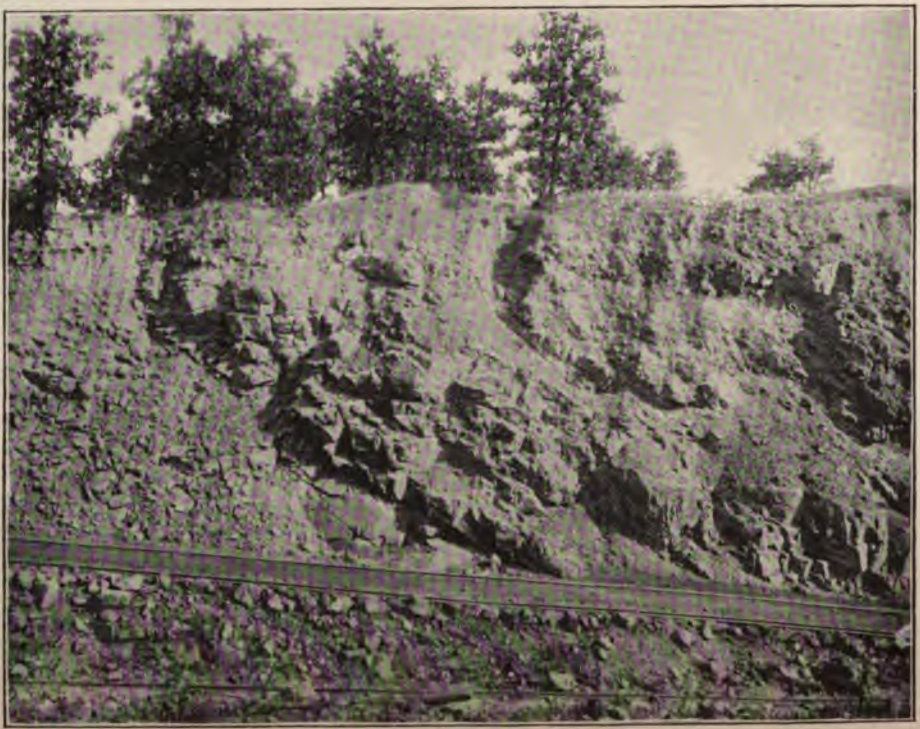
Continuing around in the same direction, to the right, the southwestern corner of the pit is still of the same clayey material. A large part of this wall, however, is so filled with nodules of specular iron that it is being washed with profit. This part of the mine pit is shown in Plate V., in the dark part in the upper left hand corner of the plate. Under this spot, and to the right (in the plate), strata of shaly sandstone again begin to appear as shown. This illustration also exhibits very plainly the sandstone layers dipping steeply towards the center. In the extreme upper right hand corner solid sandstone of the same nature appears as that shown in Fig. 1, Plate VI., at the north end of the mine.

of the clay is fine boulre.

About two hundred feet to the north of this last mentioned point, the track, used for tramming the ore to the railroad, cuts through the wall of sandstone. Plate VII. shows the position of these sandstone rocks, in the cut. This view is taken looking north. In this plate a good idea of the disturbed condition of the sandstone is to be had. It will be observed that the rock is folded and that the axis of the fold dips towards the observer.

sturbed ition of the stone.

North of this cut, towards the city of Salem and along the line of the branch railroad, these sandstones appear to be nearly horizontal in places.



View of Cut at Simmons Mountain mine. On tram road west of mine, showing disturbed sandstone. The dip is southwards toward the observer.

Reproduced from a photograph.

The mine pit itself is, as was stated by Dr. Schmidt, about five hundred feet long and about four hundred feet wide measured across the top of the opening. The mine is worked wholly underground at the present time and this much of the particular structure of the pit is obscured by the wash from the softer part of the walls.

Immediately under the point shown in Plate VI. the slope extends down into the pit for about one hundred feet and then passes underground. Under this slope the ground is very nearly as is shown in Fig. 43. It is not solid but is made up wholly of masses of angular blocks of broken chert and some oölitic sandstone. The interstices of this breccia are filled entirely with specular ore. These blocks appear to be wholly or partially buried in clay of various colors. Some of the clay is of a bright vermilion, other parts are of a dirty brick red color. Mingled with this is decomposed chert, almost pure white and often mistaken for clay. This slope runs towards the south.

Underground the rock is a breccia.

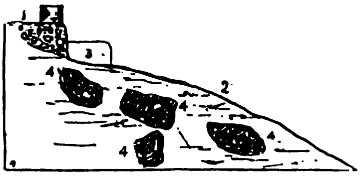


FIG. 43. Incline at Simmons Mountain.
1 is north wall of mine shown in Plate VI.
2 is slope down to mine.
3 is part of ore body now mined out.
4 are blocks of brecciated chert and sandstone cemented with specular ore.

Referring to Plate VII. it will be seen that the part of the rock which appears near the center of the plate slopes nearly directly to the east. It could be easily imagined then that, at some point, the ore body will be cut out by this rock and this is just what happens. From near the bottom of the present slope drifts extended east and west from the ore body meet this rock and find the ore entirely cut out.[1]

Sandstone apparently goes under the ore body.

Comparing this description with the one which Dr. Schmidt has given in the paragraphs quoted from his report, it seems that, in a way, his estimate of the slope of the ore body was correct, although its magnitude did not come up to his expectations.

Principles Taught by this Deposit. In the study of this particular ore body there were many facts noted that may be of

[1] The sandstone probably lies on the limestone which forms the walls of the cavern in which the ore was deposited.

general importance as throwing light upon the origin of these ores as well as the structure of the deposits in general. As has already been indicated the shape of this ore body is nearly that of an elliptical, inverted cone. On all sides, at a short distance from the mine, and immediately at the mine on the western and northwestern sides, there is sandstone. At a short distance from the mine this sandstone is nearly or quite horizontal. In the immediate vicinity of the mine these same sandstones are folded and suddenly dip towards a common center. The mine pit itself, as excavated, closely resembles the numerous sink holes which exist not only in this locality but which are met with throughout the wole extent of the Ozark Uplift. Not only are the sandstones broken in the vicinity but at the mine itself they seem actually to have disappeared. Chert, which appears rarely in the sandstones generally, is common in the sandstone blocks in the body of this mine. This sandstone is characteristically oölitic and this oölitic structure is persistent in the rocks which fringe the mine, but it grows less common as one goes from the mine.

xcavated e resembles ık-hole.

The appearance of the rocks in the mine body, their disturbed appearance on the borders of the mine, together with the shape of the ore body, seem to support most strongly the view discussed more fully later, that this whole formation is underlain by limestone beds and that at this particular point the limestone has been etched out, letting the superincumbent sandstone beds fall in in broken fragments, that subsequent circulation of waters cut out much of this standstone and reduced much of the silica to the colloidal state, thus giving rise to the numerous chert nodules.

ljacent support view.

The iron ore must have been formed after the falling in of the rock strata, for the broken pieces of chert are cemented together by iron, as are also the larger and smaller fragments of sandstone. This cementing must have been done contemporaneously with the general deposition of ore, since the iron in the interstices is as highly crystalline as is the blue ore in the main deposit.

posited af- e rocks ı.

In regard to the origin of the chert, and its influence, in the explanation of the existence of the mountain, the writer differs in a

few points from Dr. Schmidt. Dr. Schmidt seems to believe that the chert in the sandstones was one of the agents active in preserving the hill from denudation during the process of sweeping away the softer sandstones surrounding it.[1] He also regards this as being an undisturbed deposit. While there is little doubt but that the hard cherty sandstone and the ore body itself had to do with the preserving of the mountain, and in fact are the sole reasons for present prominence, there can be little or no doubt but that the ore body has been more or less disturbed since its deposition. The breaks in the blocks of ore which have been healed by crystals of hematite and veins of quartz, to say nothing of the larger cracks which break the whole ore deposit up into large blocks, all bear witness to the fact of more or less disturbance.

The mountain exists through its greater resistance to erosion.

It is highly probable that this deposit started originally as a lime sink. To the east of Simmons mountain, and to the west as well, are drainage channels which lead directly into the Meramec river. Along those drainage channels are a series of iron deposits with similar external appearances. No one of these has amounted to anything save the Simmons mountain deposit, though one within the city limits of Salem yielded a large amount of ore and it is reported to be not exhausted but abandoned on account of some dispute as to ownership. These facts strongly suggest the idea that the drainage channel to the east has caused these sinks or caves and that some of them, as Simmons mountain, were subsequently filled with ore.

This deposit originally a lime-sink.

THE CHERRY VALLEY MINES.

There are two other mines whose history it will be interesting to compare with the present condition of working. Reference is made to the two Cherry Valley banks designated as No. 1 and No. 2 by Dr. Schmidt.

At the time of the publication of Dr. Schmidt's report neither of these banks had been worked, or in fact opened. A topo-

[1] This does not at all explain how the chert came to be in the sandstone near ore bodies.

graphical sketch of these banks copied from Dr. Schmidt's report is here reproduced (Fig. 44), as well as his description of them.[1]

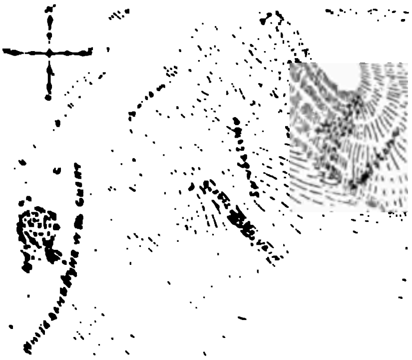


Fig. 44. Cherry Valley Bank in 1872.
H H is Specular ore.
B H. is brown hematite.

Description by Adolph Schmidt in 1872. "The western or No. 1 bank will readily be recognized as a very distinct and characteristic example of a nearly undisturbed deposit of specular ore in sandstone. The lower part of the hills of that region is Third Magnesian Limestone. The upper part of Second Sandstone. On the summit we observe an annular outcrop, several feet thick, of white and yellow Second Sandstone having in part the appearance of a vitrous quartzite, and dipping towards the center, but so steep that the strata are in most places nearly in a vertical position. Inside of this outcrop of [illegible] colored sandstone and placed conformably to it, is an an[illegible] outcrop of sandstone colored or impregnated by oxides of [illegible]

[illegible] circular space inside of these outcrops, 150 feet in diame[illegible] [illegible] covered with ore, the numerous large boulders [illegible] principally of specular ore, while most of the smaller [illegible] altered partly into limonite, partly into soft red [illegible] This space marks the position of the regular deposit [illegible] of considerable depth, filled with ore, will certainly [illegible] by future mining operations."

[illegible] gap in the sandstone outcrop on the south side. [illegible] surface ore is spread in considerable quantity [illegible] outside the outcrops, in a streak 50 to 60 feet [illegible] 200 feet long. The greater part of this surface [illegible] to limonite. An extension of the underground [illegible] cannot, however, be expected."

[1] [illegible] Survey, 1872, part I, p. 132.

"The eastern or No. 2 Cherry Valley bank, which is sketched in Fig. 44, does not show the exterior characteristics of the undisturbed bank, although it contains very large and very numerous boulders of specular ore and of limonite on the surface, and although very large masses of ore will undoubtedly be found there underground, especially in the upper part of the hill. But it is, from its present appearance, a disturbed deposit."

No. 2 bank a disturbed deposit.

The above description of the surface appearance of these two banks is extremely interesting, especially to one who is at all acquainted with their subsequent history. Viewed properly it may also afford considerable encouragement to prospectors who are searching for other ore deposits in this region. From Dr. Schmidt's report, as well as from the estimated value, the western or No. 1 bank was far more promising than was No. 2 or the eastern bank. Actual working, however, has reversed this estimate. The western bank is now abandoned, having produced only a few thousand tons of ore, probably about ten thousand tons,[1] while the eastern bank has already produced over four hundred thousand tons with a promise of a good many more.

Exploitation shows No. 2 bank to be the better.

The moral of this statement is very obvious and will be emphasized later. If a deposit of such extent makes only a meager showing on the surface it is possible to carry this a few steps farther, to the point where a large deposit makes a comparatively no surface showing at all.

Present Conditions. In the adjoining Fig. 45 is seen the northern end of the mine as it exists to-day. The part mined out is a large pit about four hundred feet long, three hundred feet wide and about one hundred feet deep.

Dimensions of No. 2 bank.

FIG. 45. Sketch section of the northern end of the Cherry Valley mine.
1 *is clay detritus;*
2 *is sandstone dipping towards the mine;*
3 *is cherty stratified and slaty clay;*
4 *is the ore body;*
5 *are the broken blocks of sandstone.*

[1] This bank is not yet exhausted, and there is said to be much more workable ore in sight. It is temporarily abandoned since the other bank is more satisfactory in working.

At present, the northern end of the mine, shown in the sketch, is being worked. As is there seen also, and as is the case with the mine at Simmons mountain, sandstone forms the greater part of the country rock of the mine and it abuts sharply against the ore.[1] (See 2 and 4 in the sketch.)

A study of the rocks lying at some distance from the ore body reveals the following facts, which are strictly in accord with the theory to be discussed later in this report.

ıding hills ıd with tone.

The summits of the hills which surround the Cherry Valley bank on nearly every side are capped with sandstone lying horizontally. At the company's store this sandstone crops out so abundantly that there can be no doubt of the truth of this statement. Passing down a steep descent from the store to the edge of the mine the barometer indicates a difference of level of one hundred and fifty feet. As was before stated, the border rock here is also sandstone.

ge trench s decom- limestone.

At the northern end of the mine, however, there are tolerably sure indications that the sandstone which crops out at the store has been succeeded by limestone at a point much above the surface level at the mine. At this northern end a deep trench is cut to carry away the surface water, thus preventing its running into the mine. In digging this trench it was necessary to tunnel through a projecting point. This tunnel passes through layers of decomposed chert which are interstratified with layers of clay and gritty, clay slate. At the southern end of the mine the company is stripping off the overlying dirt preparatory to removing another large breast of ore, a continuation of the main ore body. After removing a large mass of dirt consisting of unstratified clay and chert with occasional boulders of specular ore, a tolerably continuous bed of sandstone was met with. Immediately under

[1] This statement, unmodified, is liable to be misleading. It must be remembered that the term "country rock" is confined to the rock which actually appears in contact with the ore at the surface border of the mine. From the careful study of the mine it is seen that drifts run in from either side of the open cut would show that the true country rock is limestone lying in undisturbed horizontal layers. The sandstone which appears dipping steeply towards the ore body is but the broken and disturbed fragments of what was formerly a continuous bed overlying the limestone in which the ore body is situated.

this lie successive layers of well stratified, fat, reddish, and yellowish clay, chert and slaty rock almost wholly free from iron boulders.

Again starting from the point already referred to as lying one hundred and fifty-six feet below the sandstone at the store, and following down the ravine in which the ore body lies, solid beds of horizontal limestone are found at a point, by the barometer, only twenty feet below the level of the surface at the mine. Following this limestone up another ravine which runs at right angles to, and east of the ore body, this limestone is found outcropping in successive layers to a point eighty feet above the level of the mine.

Beds of solid limestone are found.

This means that the thickness of the sandstone, from the store down towards the mine, is only seventy-six feet at most. In other words the present surface level of the ore body is eighty feet at least below the level of the top of the limestone beds in which it is situated. There are many other minor facts all of which point to the conclusion that this ore body, and probably all other specular ore deposits in this region, are situated *in* the limestone and *under* the sandstone with which they appear to be associated.

Maximum thickness of sandstone.

Attitude of Sandstones Explained. If this view of the case is adhered to it may be asked how can the sandstone, which invariably accompanies these specûlar ores, be accounted for.

At Cherry Valley this will be a little more difficult than in some other localities, since the depression, in which this bank lies, is at least three thousand feet across. But even here, if the phenomena of undermining of the sandstone by the dissolving out of the limestone be kept in mind, the explanation is simple. Imagining the strata of sandstone and limestone replaced in the positions they had before erosion began, we shall have a continuous bed of sandstone stretching from hill point to hill point across the entire valley. The drainage being at the southeast we can imagine the eroding waters etching away the underlying limestone little by little, thus allowing the sandstone to settle, more or less broken, to a lower level. As time goes on, the flowing waters are concentrated into a more definite channel until the sandstone bridges a comparatively narrow cave. Finally

[illegible] Valley due [illegible] extended [illegible] underground [illegible] erosion

the removal of the limestone reaches a point where the sandstone can no longer sustain its weight and it falls in towards the cave, leaving what was before an underground stream now exposed to the open air. The broken fragments of sandstone which fall to the bottom are slowly removed by the water. The sandstones lying on either side, also more or less broken, have long since been removed by surface erosion. Fig. 2 of Plate VI., opposite p. 125 and Plate VIII., opposite this page, illustrate graphically the history of this movement to the present condition. Plate VIII. shows the position of the mine in a basin of a former drainage channel. Plate VI. shows the sandstone, with its underlying strata of the cherty, slaty clay dipping towards the mine, seen in the background. The adjoining Fig. 46 illustrates diagrammatically the relations of the various rocks exposed.

[illegible] country rock and ore at the [illegible] mine.

[illegible]

[illegible]

View of Cherry Valley mine showing its location in a former drainage basin.
From a photograph.

the enclosing rocks, let us examine the particular structure of the mine.

Along the entire eastern wall this sandstone stretches, and is so hard and abuts so sharply against the ore that it stands almost perpendicularly. For two feet or more into the face of this sandstone the stone looks more like specular ore than sandstone, so thoroughly is it impregnated with iron. Going back from this face the iron grows less and less in amount until the rock reaches a condition of great friability, characteristic of the greater part of the sandstone of this region. Along the western side of the mine no sandstone to speak of appears. Such as does appear is in the form of large cherty boulders mostly oölitic. Back from this side the same condition of things holds until the foot of a hill is reached which is sandstone. There seems to be little or no iron imbedded in the loose clayey, cherty soil. The iron seems to have entirely given out in this direction.

Sandstone appears to be th immediate wa rock.

Around the entire northern end of the excavation a deep sluice is cut to prevent surface water from entering the mine. The trench cuts through the rocks at 3 in Fig. 46. At the northwestern corner this sluice is carried by a tunnel, about one hundred feet long, through the rocks. This tunnel reveals the condition of the rocks that is shown in the figure. The formation on that side of the mine is made up entirely of rotted limestone, represented by strata of clay intermixed with chert nodules. This clay is generally stained a dark red and contains lenses made up wholly of white decomposed chert. Lenses of sandstone also occur. From the general appearance of the rocks on this side of the mine it would be concluded that the series of clays is, as was stated, nothing but the remnants of a bed of limestones. The alternating layers of slate and sandstone in the clay, more frequent as the main body of sandstone is approached, would seem to point out that this represented the transition series from the limestone to the overlying sandstone. In this transition series a part of the main ore body seems to be. At the southern end of the mine preparations are being made to push the mining of the ore in that direction. A tunnel or drift ninety feet long has been run in that course and the end of the ore has not yet been reached.

Former existenc of limestone.

the removal of the limestone reaches a point where the sandstone can no longer sustain its weight and it falls in towards the cave, leaving what was before an underground stream now exposed to the open air. The broken fragments of sandstone which fall to the bottom are slowly removed by the water. The sandstones lying on either side, also more or less broken, have long since been removed by surface erosion. Fig. 2 of Plate VI., opposite p. 125 and Plate VIII., opposite this page, illustrate graphically the history of this movement to the present condition. Plate VIII. shows the position of the mine in a basin of a former drainage channel. Plate VI. shows the sandstone, with its underlying strata of the cherty, slaty clay dipping towards the mine, seen in the bankground. The adjoining Fig. 46 illustrates diagrammatically the relations of the various rocks exposed.

herry Valley due to extended underground erosion.

FIG. 46. Section showing the relative positions of country rock and ore at the Cherry Valley mine.

1 *is sandstone in place;*
2 *is a slaty, clayey layer with fossiliferous chert;*
3 *is disturbed sandstone, the apparent wall rock;*
4 *is magnesian limestone, the real wall rock.*

It may be asked why, if these sandstones have been undermined and thus allowed to settle down, the sandstone caps of the hills do not also settle. There is no doubt but that such settling is in progress now. There is little doubt but that this slow process of undermining and settling is slowly and surely going on at the present time. A full discussion of this question would be out of place here, but the close observer of the drainage of the entire Ozark system will hardly fail to reach this conclusion.[1]

he sandstones are being undermined now.

Conditions Affecting the Extension of the Ore Deposit. Having thus explained the relative positions of the ore body to

[1] See Chapter on General Geology of the Ozarks, p. 85.

difference lie in the facts that while the Simmons mountain deposit is pyramidal in shape, the Cherry Valley bank No. 2 is more prismatic. Simmons mountain deposit is inclosed by rocks on every side while, up to this date, the walls on only two sides of the Cherry Valley bank have been located. Cherry Valley bank No. 1, the westerly of the two deposits is, according to our present knowledge, more like the deposit at Simmons mountain; its shape is more like an inverted cone and the rocks, so far as they can be observed, dip slightly towards the center. The deposit is, however, much smaller. Like the other deposits described it too lies in proximity to a large ravine or drainage basin.

Cherry Valley and Simmons mountain have many points in common.

Peculiarities of the Ores. The ores of the Cherry Valley bank are in many respects unique so far as this region is concerned. While they are generally close grained blue and specular, there are a great many geodes which are lined with highly irridescent but small crystals of hematite. There are also geodes lined with amethystine quartz some of them of very large size. The principal interest attached to these facts is that many of the quartz crystals have included in their mass crystals of hematite. Also cavities in the quartz crystals, though very minute are yet large enough to show them to be filled with a fluid, probably water.

Crystals of hematite and amethyst at Cherry Valley.

These facts point to the conclusion that water played a very important part in the origin of the ore body. The fluid cavities in the crystals of quartz, as well as the quartz crystals themselves indicate crystallization from water, while the included scales of hematite show that conditions existed, whatever they were, such as to permit the precipitation of anhydrous specular ore from a water solution.

The ores of aqueous origin.

The occurrence of fossils in the specular ores is another fact pointing strongly to their probable aqueous origin. These fossils were first observed by Mr. Jas. D. Robertson of the Survey staff. The fossils consists principally, so far as observed, of casts of crinoid stems. The walls of the long straight tube are lined with minute scales of hematite. In one instance a slender rod, with regular joints, composed entirely of crystals of hematite reached from end to end of the tubular cavity. The bulk of the specimens is compact, massive, specular ore. In short the specimen was a tolerably accurate reproduction of

the fossiliferous chert of the Lower Carboniferous which are found scattered over the whole of the Ozark Uplift.

Having now described the main features of these deposits, we will next take up a discussion of the probable origin of the ores.

THE ORIGIN OF THE SPECULAR ORES IN SANDSTONE.

Concerning the origin and mode of accumulation of the ores, the following conclusions have been reached, from our studies in the region.

First, that there were probably many hundreds of feet of alternating beds of limestone and sandstone above the present exposed beds.

Second, that, with the inception of the Ozark Uplift, there began a system of denudation by means of surface and subterranean erosion.

ons tudy of ts.

Third, that the underground erosion cut out great caves which undermined the sandstones and allowed them to fall in.

Fourth, that the underground drainage ways were occasionally choked, thus allowing the accumulation of iron or other matter.

Fifth, that the falling of the insoluble sandstone roof, layers or beds of limestone above, with their layers of chert, would also gradually bend in and finally become broken.

Sixth, that this breaking of the limestone allowed percolating waters charged with iron to pass through, thus gradually replacing the soluble rock with iron.

Seventh, that the iron of these deposits was derived by percolation from the overlying and adjacent rocks.[1]

Evidence of Past Erosion. As a proof of the first statement, it is a well known fact that, in sheltered places, there are deep beds of clay and loam regularly interstratified with each other and with beds of chert. These beds of clay, when pure, undoubtedly represent a bed of aluminous limestone. Sandy beds represent less pure limestone. We are prevented from arriving at an estimate of the thickness of the overlying beds by the fact

[1] As bearing upon this question, for a full discussion of the peculiar topography of the Ozark Uplift and the causes which gave rise to it, see Chapter V, on the General Geology of the Ozark Uplift.

that a bed of pure limestone would leave absolutely no trace. There are layers of white substance which looks much like kaolin, and by many it has been mistaken for clay. As a matter of fact, these deposits are only decomposed chert. They are white because the chert itself had little or no iron in it, originally, and because the chert has decomposed after the decomposition of the limestone, thus escaping being stained by the iron in that rock. There are white clays but the prevailing color is bright red to dark reddish brown. Even in the region where there is the greatest exposure of sandstone this is true, so the conclusion is inevitable that heavy beds of cherty limestone once existed above the present rocks.[1]

Beds of clay remnants of former limestone beds.

Evidence of Underground Erosion. In regard to the second fact one can find abundant proof. This undermining is constantly going on at the present time. Its action in the past is beautifully shown near Cook's Station on the Salem and Little Rock R. R. Three miles from this station on the Sligo branch R. R. is a deposit of coal. This bed of coal is eight feet thick from wall to wall, and it bends on itself at an angle of forty-five degrees. As is shown in the adjoining Fig. 47, shafts have been sunk in at two points. One shaft is eighty feet deep, the other forty feet, the foot and hanging wall, each a loosely compacted clay shale, dip at an angle of about ninety degrees. The sandstones, between the outcrops of which this coal pocket lies, are nearly horizontal. The coal is crushed and "slickensided" thus showing that it has been greatly disturbed.

Coal pocket in Dent county.

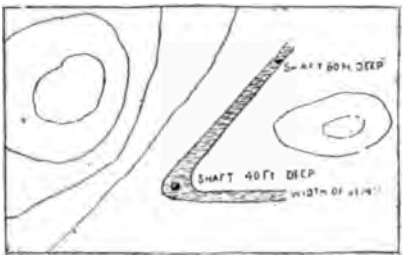


FIG. 47. Sketch showing plan near Cook's Station on the Salem branch of the St. L. & S. F. Ry.

Near Climax Springs, in Camden county, is another coal pocket. In this case there is no coal, only soft clay shales with abundant coal plants. These shales dip towards each other in a sharp "V," while on either side the magnesian limestones lie nearly horizontal.

Camden county.

[1] See evidence establishing this fact in Chapter on General Geology, p. 93.

Another series of striking facts are presented in the cuts on the railroad from Cuba to Midland Furnace. These are a succession of low hills, each of which is flanked by sandstone dipping away from the crests, thus forming a series of apparent anticlinal and synclinal folds. That these are not the result of folding is proved by the fact that the crests of the apparent anticlines are without exception, made up of horizontal beds of limestone, and the inclined sandstones lie on the eroded edges. The cause of this structure is the etching away of the underlying limestones by former underground streams causing the overlying sandstone to break and fall in.[1]

Apparent anticlines south of Cuba.

These, and other such facts, abundantly prove that underground streams have played an important part in the topography of the country. They also warrant the third and fourth statements which were made, for, the underground waters would, thus, both remove the soluble limestone and allow the insoluble sandstones and slates above gradually to fall in. If the stream was of sufficient force the falling debris was removed by erosion, and the result was an open stream; if not, the waters turned elsewhere or sunk deeper underground.

Mode of Ore Accumulation. It is very evident if these underground streams became choked or impeded in any way by falling debris, the point at which the choking occurred would be favorable to the accumulation of iron or other matter which the water had in solution. The falling in from above of another layer of either sandstone, or chert with the accompanying limestone, would inevitably be attended with more or less fracturing of overlying strata and, through these fractures, percolating waters would surely find their way. These waters, coming from the surface and charged with organic acids, would by leaching through the overlying strata, take out all of the iron and this iron would be, or at least might be, precipitated by sulphuretted hydrogen. Thus while the water along the subterranean channels was dissolving the carbonates of lime and magnesia, the iron from percolating waters would slowly take its place and often preserve the minute struct-

Organic acids aid in leaching rocks.

[1] It is fair to question as to whether or not the greater part of the streams now runing on the surface did not originally start in underground streams.

ure of the original limestone beds. Thus beds of broken chert would appear with their interstices filled with specular iron, beds of bright red clay and again beds of almost pure ore.

The source of the iron in these deposits of the Ozark, as has already been mentioned, was probably from the overlying beds. The reasons for assuming this are very plain. This region is beyond glacial action and the rocks have rotted in place. There are but a few remnants of younger formations. These, if they existed, must have been swept away. The Coal Measure and Lower Carboniferous rocks, are the ones to which we would naturally look as the source of the iron in the lower rocks, but these are absent except in isolated places. The existence of fossil crinoids in the iron ores of Cherry Valley; the existence of crinoidal chert scattered over the highest points of the Ozark Uplift, together with the known deposits, in isolated patches, of Lower Carboniferous rocks, all these seem to indicate the former extension of this group over a great part of the Ozark series of rocks. As has elsewhere been pointed out this group of rocks in other places carries bedded red hematites. It would seem reasonable to infer that if they existed here, here also they would carry red hematite. But we have no means of knowing the former magnitude of this group; much less, as to whether it carried iron in abundance. If it did the iron must have been dissolved and redeposited in the places where we now find it.

Remains of younger beds.

The preponderance of evidence, however, is in favor of the assumption that the iron, accumulated under these conditions, has been derived from the existing sandstones and from the overlying beds of limestone and sandstone which have been broken down and in part swept away by erosion.

Iron derived from existing rocks.

It *must* have had its origin from one of the following sources. First, it may have been brought from below by springs, in accordance with what is known as the crenetic hypothesis of Dr. T. Sterry Hunt. Second, it may have been precipitated from sea water. Third, it may have been derived from the removal, by solution, of iron from pre-existing beds in the Coal Measures; or, fourth, it may have been derived by leaching and concentration from the overlying and adjacent rocks.

Possible sources of the iron.

The first of these propositions may be dismissed with no dis-

cussion, merely stating that the limonites occur as stalactites, in many cases, showing that the course of the water was from above downwards; and that the specular iron ores occur in precisely the same manner in cave-like depressions in the limestones which have been etched from under the sandstones. In the second case if the iron had been precipitated from sea water it would have been found in beds of varying thicknesses and of cotemporaneous origin. No beds exist and all the iron found is evidently secondary in origin as has been abundantly shown. The third and fourth propositions are practically the same, for whether the iron existed in beds in the Coal Measures, or was disseminated in the limestones and sandstones, there is no way to account for its accumulation in its present form except by leaching and by precipitation from percolating waters.

The probable sources.

The clay which results from the decomposition of the present magnesian limestones is uniformly tinged with iron, and in places, there are good size deposits of almost pure ocher. The sandstones which accompany these limestones, as they generally exist now, are remarkable for their freedom from iron and from other impurities, although there are places where they are highly ferruginious. They are so friable usually as to be easily crushed in the hand. Similar rock is mined in large quantities at Pacific and Crystal City, Mo., to be used in the manufacture of glass. What more natural than to assume that these sandstones were originally ferruginous, as they are in places now, and that the iron which formerly made them compact and strong has been gradually leached from them until they are now practically beds of pure sand.

Clays tinged with iron.

Evidences of Metamorphism. The question as to why these particular ores are specular, while the ores of Southern Missouri are brown hematites, can be answered in the following manner. In this region the chert is almost universally oölitic as well as the accompanying sandstone. The sandstone in places has lost its granular structure; has in fact almost wholly lost its oölitic structure and appears almost cherty. This is markedly true in the vicinity of specular ore deposits. If, now, we account for the chert in the limestone by assuming,

which is undoubtedly possible, that it represents fine silica which has assumed the colloidal form, the same must be true of the chert layers and the chert nodules in the sandstone. The limestones of the Ozark series are almost universally crystalline, but not in a high degree. They are yet limestones and in no sense marbles. Fossils are rarely found in them; when they are found they are siliceous casts. The fossil forms which are found are of a high order, and they are found in such a manner as to lead us to infer that life was very abundant in these early Cambrian seas. This dearth of fossil remains and the other facts point strongly to metamorphic action, not to intense action, for all of the phenomena could take place with water which was not raised above the boiling point except in the immediate vicinity of the banks. The assumption of only a moderate thickness of overlying beds is amply sufficient to account for this general rise in temperature. Oölitic chert.

E. Davies[1] has shown that the iron precipitated in boiling water is far less hydrated than when precipitated at normal temperature, and infers that, at a little higher point of temperature, anhydrous oxide of iron would be thrown down. To show that there has been water hot enough to dissolve silica it may be stated that, at the Cherry Valley bank, there are numerous quartz crystals; that, inclosed in the crystals, are minute crystals of hematite, further shows that anhydrous oxides of iron can be precipitated from an aqueous solution. The quartz also is often filled with acicular crystals of an unknown mineral. Precipitation of anhydrous oxides of iron.

The Dehydration of the Ores. Metamorphism is more marked in the immediate vicinity of the ore bodies but extends only a slight distance from them. The ore deposits on the surface, and along the fissures that extend into the bodies, are changed to limonite or to red hematite. The great bulk of the large bodies are compact, completely, though finely crystalline, they have cavities of small size lined with amethystine and limpid quartz and with small crystals of hematite, and jasper and crystalline quartz. The bottom of the larger deposits is usually, so far as known, composed of sulphide of iron, some- Sulphides with the specular ores.

[1] Jour. Chem. Society, Vol. II, p. 69.

times in large lenses, sometimes as small crystals, infinite in number, scattered through clay and decomposed chert. At Cherry Valley this sulphide is known to be at least twenty feet deep, and at the old Scotia bank it is reported that this sulphide was found, by means of a drill, to a depth of one hundred feet. Arsenic, copper, antimony, zinc and lead are found in all of the specular ores in greater or less abundance, though still in very small amounts. In addition there is yet much sulphur though not in injurious quantities, in the ores themselves.

Specular ore in unmetamorphosed rock.

Were it possible to conceive of the deposits of specular ore being bedded, and thus of contemporaneous origin with the rocks in which they occur, we would yet be confronted with the difficulty of explaining the presence of a highly metamorphosed bed of ore in a comparatively unmetamorphosed rock, for the ore beds could hardly be conceived as being contemporaneously deposited as specular ore. But unfortunately we have to acknowledge that they are not bedded deposits.

It will be borne in mind that the rocks of the Ozark Uplift are probably of Cambrian age. There is pretty strong evidence that Lower Carboniferous rock, to some extent at least, covered the Uplift. This, however, does not simplify the explanation of the highly crystalline state of the specular ores, for if they were buried deeply enough to cause their metamorphism, the rocks which inclosed them ought also to be highly metamorphosed.

Iron precipitated as a sulphite.

Let us start with the hypothesis that they were originally deposited as sulphides. We can easily imagine this to be true, for the rocks from which the iron was probably obtained were full of organic remains. These, in decomposing, would furnish enough sulphuretted hydrogen to cause the iron to be precipitated as sulphide. The abundance of sulphur is amply testified to by the fact that barium, zinc, lead and iron are even now found united with sulphur in the form of sulphides and sulphates. The history of a large deposit of sulphide of iron can be traced out with at least a strong probability of correctness. Sulphide of iron is a very unstable mineral generally, and, decomposing even with moderate rapidity, a great amount of heat will of necessity be generated. With a supply of oxygenated water, sufficient to oxidize the sulphur and iron, a degree of heat would be

developed sufficient to insure the solution of peroxide of iron and its precipitation in the crystalline form. The volume of circulating water must not, in a case of this kind, be great enough to dissipate the heat evolved by the decomposing sulphides as rapidly as it is evolved. This is the only serious difficulty in the way of this explanation. But, inclosed as the specular deposits are by walls of poorly conducting sandstones and limestones, little or no heat, thus generated, would be lost by radiation. Compared with the difficulties which this theory of local metamorphism obviates, the difficulty of explaining how the water supply was ample for oxidizing processes and not great enough to dissipate the heat generated, is simple. Local metamorphism induced by decomposing pyrite is strictly in accord with the observed facts before pointed out. The sandstones in the immediate vicinity of the ore body present evidence of a change more intense than the great mass of the rocks. The induration of the sandstone; the formation of the oölitic chert, or rather the conversion of the large masses of sandstone into an imperfectly cherty mass with limpid grains surrounded by colloidal silica; the formation of large quartz crystals in the ore with fibrous minerals and crystals of hematite included, as well as liquid cavities, the change of silica into jasper and this into vitreous quartz, all these facts point strongly to local agencies rather than to a wide-spread and powerful action.[1] Without attempting to dogmatize, the conclusion has been reached by the writer that original deposition as sulphides, and subsequent metamorphism induced by decomposition, satisfies the conditions of the problem of the specular ores of the sandstone region better than does any other. It may further be pointed out, in support of the above hypothesis, that the iron ore body, at Cherry Valley, a breast seventy-five feet high and one hundred feet wide, is seen to be completely broken up into angular fragments of varying sizes. The appearance is very

Its decomposition evolves heat.

Broken conditions of ores due to loss of heat.

[1] These are some of the facts noted by Irving, Van Hise, Winchell and others and adduced by them in support of their views in the formation of the jasper ores of the Lake Superior region, as evidencing the metamorphosing of the specular ores of that region, though there the agent was eruptive rocks, and the metamorphism regional.

Decomposing sulphides generate high temperature.

much as if the original body of specular ore had been highly heated and that these checks and seams were the result of cooling. There are so many and such well known examples of high temperature being generated by decomposing sulphides that this point will be assumed without discussion. If the fossils in the specular ores prove them to be of past Lower Carboniferous age the above conclusion is not necessarily affected. The fossils can have been replaced by iron in the form of a sulphide and afterwards, without change of form even if of volume, the iron can have parted with its sulphur and changed to the peroxide state. Limonite pseudomorph after pyrite shows that a change in composition without change of form is possible. The only modification of the above conclusion, which the fossils may introduce, is as to the period of geological time in which the specular ores were deposited.

PROSPECTS FOR THE FUTURE.

There are probably hidden deposits.

Aside from the very interesting geological problems which the study of the mines of specular ore in this region propound, there is another and a very practical side to the problems. It is a fact, as before stated, that no new mines are being opened in this region and the old ones seem to be well on the way to exhaustion. Moreover, there seems to be a general belief that there are no more extensive deposits in the whole of this really vast region. This belief appears to be founded chiefly on general impressions and on the failure of the mineral prospectors to discover other paying properties. The facts are simply that all deposits now being worked were originally exposed at the surface and that very many surface deposits on being explored failed to yield a large amount of ore. Sober thought will certainly lead to the conclusion that this is exactly what would naturally be expected; but the former overestimate of the resources of this section of the State in iron ores has reacted and has pushed opinion to the other extreme. One thing certainly seems to be lost sight of. In a region which has so many surface deposits of iron extending into the rocks beneath there is ample reason for supposing that there are other and equally extensive deposits which give no surface indication.

This statement should not be misunderstood nor misapplied, which may be very easily done, and if followed out without understanding every step in the process it will surely result disastrously.

In this region in many places are found large nuggets of lead ore and zinc as well, imbedded in the clay which overlies the limestones. The ore is often abundant enough so that digging for it in the loose clay yields profitable returns. When solid rock is reached shafts have been sunk, oftentimes many feet in depth, in order to strike the "vein." Disappointment has generally resulted and for the following reasons. The superincumbent clay which lies upon these limestones is often the residue from the rotting away of many hundreds of feet of limestones that formerly overlaid the present beds. In these superincumbent beds were cavities, more or less numerous, filled with galena or lead ore, which being almost wholly insoluble, was slowly concentrated in nearly one position, either in ravines at the foot of hills or other favorable spots, with the rotting away of the limestone. In any case the miner who finds one of these pockets, within a vertical distance of fifty feet or less, recovers nearly all of the ore which was held in hundreds of feet of limestone above, and from which directly profitable excavation would in many cases have been impossible. When the solid rock is reached below the same conditions obtain which were formerly extant above. Only occasional "pockets" of ore are found.

Lead and zinc ores concentrated by removal by solution of limestone.

In the iron region, especially in the limonite region, the same conditions under which lead and zinc accumulated, favored the accumulation and subsequent concentrating of the iron ore in the overlying clay. Under the original conditions when the iron was enclosed in cavities in the solid limestone the prospecting for iron ores, even when there were surface indications, would be of little avail, much less than in the case of lead, which is a more valuable metal.

Iron ores concentrated in the same way.

The study of the mines of the sandstone region give the following general facts which apply to one mine as well as to another.

1st. The mines occur in connection with sandstones without any important exception.

2d. These sandstones, in the immediate vicinity of the mines, are, without exception, greatly disturbed and they usually dip towards a common center.

3d. The dip towards a common center is also towards a sunken part of the field, or at least the center is usually lower than the general level.[1]

sions.

4th. In the center of the depression there is an absence of bedded rocks and, usually, there is much clay, beneath which is the ore body which occurs in layers.

5th. These mines are located at the head of, or at least in immediate connection with drainage areas, like the beds of brooks or of larger streams.

r origin for res.

As has been stated, these facts are very prominent at all the mines in the sandstone specular ore regions which have been successfully operated. The deposits of iron ore which have not been worked, but simply make a surface showing, also have the same general characteristics. The legitimate inference is then that all of these deposits have a common or at least a similar origin. This origin has been briefly outlined on page 138 and in the chapter on General Geology.

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Existence of Buried Deposits Probable. Carrying out the ideas there outlined to their legitimate ends we find no objections to concluding that any one of these drainage systems and such points of possible seggregation of specular ores, could be wholly underground and thus that ore bodies could exist giving no surface indication of iron. Farther, the depression which would invariably be caused by the falling in of the sandstone layer, would tend to gradually fill with loose materials, such as clay, sand and loam. This filling would tend to still more cover any seggregation of iron ore which had gone on. This filling in with loose material may even be going on at the present day.

Simmons mountain, unlike the majority of the specular ore deposits, stands out in relief above the surrounding country instead of below it. It has a conical shape and is about ninety feet high. It is practically isolated from other hills. It

[1] The surface of the mine at Cherry Valley is 157 feet below the store. The hills which surround it on nearly every side are at least this height above the mine also. The mine itself is about 100 feet deep.

will occur to many that this is a prominent obstacle against the adoption of the conclusions expressed above. But it must be remembered that the Simmons mountain deposit occurs on a plateau. The reason for its standing above the surrounding country is due to the fact that, after the deposit was formed, it acted as a barrier to eroding forces, and, while the softer rocks were etched away, this, being harder, remained. Its elevation above the surrounding country is not much over ninety feet.

It will thus be seen that many deposits may thus be entirely placed beyond the observations of the ordinary prospector. It is just here that a knowledge of the geological structure of the iron deposits of this region, together with a correct theory of the origin of the iron ores, may be of the highest practical value in supplementing the knowledge of the miner and prospector. A region or a particular spot which shows absolutely no actual signs of iron, may yet have the common characteristics of a paying ore bank. The bending of the sandstone toward a common center, the absence of rocks at this center, the accumulation of broken sandstone with broken chert in thick layers of clay or sandy loam, all point to a subterranean drainage area in the form of an underground stream or a sink hole. These, as experience has shown, point to a place where accumulation or segregation of iron ore has taken place. And these indications are favorable for search for hidden deposits.

The value of geological data in prospecting.

This suggestion is not purely speculative or theoretical. In the iron regions of New Jersey one of the most valuable and extensive deposits of magnetic iron which is now being worked showed no trace of its existence on the surface to the ordinary prospector. It was located chiefly by the knowledge of the geological structure of the iron ore deposits in general, as revealed by their workings. It is true that the iron deposits of the region under consideration, are different in every respect from the magnetic iron ore belt of New Jersey, but the force of the principle is equally apparent.

Hidden deposits located elsewhere.

The Causey Bank. Of more direct bearing is a fact which came to the notice of the Survey during the past summer. In township 34, N. R. 7 W., Sec. 35, on the property of Mr. A. C. Causey, there is a deposit of ore which was found under peculiar

circumstances. There were no traces of iron on the surface with the exception of a little lean sandy and clayey limonite and broken chert and sandstone with iron stains. So far as any indications of an ore deposit are concerned, there are hundreds of other locations whose surface indications are far more promising. Here four shafts have been sunk, the deepest of which is thirty feet. An oblong trench has been cut to the depth of from ten to eighteen feet. All of these openings showed increasing traces of iron as they were sunk, and all ended in as fine appearing specular ore as has been found in this region. The successive strata from the surface down to the bottom of the shafts and trenches showed exactly the same conditions as did the Lamons bank near West Plains, Mo.,[1] and as many of the specular ore banks show in this vicinity. On the surface was much chert and sandstone imbedded in clay. Then quite irregularly stratified clay stained with iron. Then the clay grew more sandy, irregular nodules of lean limonite appeared and then large masses. Finally came large boulder-like masses of specular ore completely surrounded by limonite. The limonite had evidently been derived from the hematite by hydration.

Unfortunately the shafts were all filled with water at the time of the visit and no definite information could be gained other than that given above. No further work has been done and none is likely to be done for some time at least. The deposit is seven miles from the nearest railroad. Enough development work has not yet been done to warrant putting in a spur, and carting to the railroad is too expensive at the present price of ore. Mr. Causey does not feel able to do the necessary development work to test the extent of the ore body, and so the work stands as it is. It is to be hoped that further development will be done here. The chief interest in this connection, lies in the fact that on the surface the deposit made no showing whatever.

The geological features of this deposit differ in no essential characteristics from those of many others of this region. As shown by exploration, the body lies along the southern slope and near the bottom of a ravine or water course running to the west.

[1] See Chapter VII, of this Report.

In the bottom of the ravine there is the usual amount of sandy clay filled with broken chert in fine fragments. Occasional fragments of a highly siliceous limonite are found. Going up the slope to the south the nature of the surface changes. The side hills are covered with large angular fragments of oölitic chert and sandstone. At the top of the hill the sandstone lies in large fragments and packed so closely together that only the scantest vegetation is possible. In sinking only a short depth, in this locality, solidly bedded rock is reached.

Location is typical.

Scattered through this mass of broken rock are occasional boulders of a highly ferruginous sandstone. There are also occasional fragments both of limonite and specular ore. These latter are by no means numerous, however, and they are not much larger than a hickory nut. Only the closest observation reveals them. No bedded rocks, either of sandstone or limestone, are in sight. Along the road, however, which runs near the mine, the water has occasionally washed out deep gullies. These gullies show bands of clay alternating with cherty and slaty layers, the unmistakable evidence of a former limestone. It is, therefore, highly probable that this deposit is held in by limestone on the sides and bottom, as is explained in the case of the Cherry Valley bank.

Only scattering fragments of limonite found on surface.

Conclusions. Finally the practical conclusion from this study of the specular iron ore field may be summed up as follows: There are no valid reasons for supposing that the large deposits of iron ore which are now being worked are the only deposits of value in this field. On the contrary, there are the best of reasons for believing that intelligent prospecting will reveal other deposits of at least equal value.

In searching for these deposits it must be borne in mind that the immediate presence of level, or very nearly level, and solid beds of either sandstone or limestone are fatal to a large deposit of ore. For the reason that such solidly bedded rocks are characteristic of high sharp pointed hills and ridges with steep slopes even the presence of fair surface signs of ore on such hills are probably misleading.

Conclusions based on observed facts.

On the other hand, when on a plateau with slight elevation and with numerous sinks, or on low hills with easy slopes, at the

head of ravines and on their sides, are scattering fragments of iron mingled with clay and broken chert, the surface indications are promising enough to warrant the sinking of test pits in the clayey soil.

Not every ravine or sink hole has a concealed mine, but the general experience has been that they will exist in such places if they exist at all.

THE COMPOSITION OF THE SPECULAR ORES OF THE SANDSTONE REGION.

The specular ores of this great Ozark region are neither so widely known nor so well thought of, as a rule, as are the specular ores of the porphyry region. Yet chemical analyses show that the ores are remarkably high in metallic iron, very free from sulphur and, some of them, very low in phosphorus. Their open porous nature makes them very easily reduced in a blast furnace and, in this respect, they are superior to the ores of Iron mountain and of Pilot Knob. On the other hand, their distance from markets, the uncertain extent of the ore bodies and the irregularities of their position to a great extent counteract their more desirable features. There are no ore deposits in this region which have the uniform percentage of phosphorus which characterizes the ores of Pilot Knob, though the better grades are much lower in silica.

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Phosphorus Contents. There is a general impression that the ores, as a rule, are very high in phosphorus, but this is decidedly not the case. Chemical analyses show that, as in the case of the limonite iron ores, to which special attention is called later in the notes on Lamon's bank, some parts of the banks carry much more phosphorus than others. This, as has been pointed out at Iron mountain, is true to such an extent that while one part of the ore is so high in phosphorus as to make it undesirable, another part is so low as to make it readily available for Bessemer pig. Unlike the Iron mountain ores, however, it is the weathered ores that are highest in this element. It might occur to the reader, then, that a separation of these ores could be undertaken with profit.

horus gen- y low.

using the more phosphatic ores for mill and foundry iron, and the selected ores for Bessemer pig. The difficulty of carrying out this suggestion occurs at once, however, to one who has once visited any of these banks. The hard blue ores in this region occur in blocks of varying size and these are often completely surrounded by a thick coating of limonite, but generally with a soft red hematite. Further, in the solid blocks, seams and cavities, filled with the softer ores render this separation mechanically impossible without great additional expense.

Sulphur Contents. As has been pointed out in this chapter, sulphur occurs abundantly associated with these ores. Fortunately, however, this element is so seggregated as to present no difficulties in shipping an ore which analysis will show to be very low in sulphur. It occurs very infrequently in isolated bunches in the ore mass, but is found in the bottoms or on the sides of the banks in considerable abundance. There are other impurities which occur, but in such minute quantities as to do absolutely no harm and they have generally escaped notice. Copper, lead, zinc and arsenic have all been observed by the writer, principally in the form of sulphides.

Sulphur is seggregated.

Of the four blast furnaces which have been erected in this region only two are now in operation, one at Midland and the other at Sligo. These furnaces depend upon charcoal for fuel and use the local magnesian limestone as a flux. They produce beautiful gray pig iron which commands a high price. Charcoal is used exclusively as a fuel.

Dent County Ores. The following partial analyses of specular ores from Dent county are taken from Vol. XV. of the Tenth U. S. Census Reports:—

	1 Per cent.	2 Per cent.
Metallic iron	63.77	67.02
Phosphorus	0.061	0.025
Phosphorus ratio	0.096	0.037

	3 Per cent.	4 Per cent.
Metallic iron	63.90	64.05
Sulphur	0.020	0.179
Phosphorus	0.029	0.063
Phosphorus ratio	0.045	0.098

Samples 1 and 2 were taken from the old Nova Scotia bank. No. 1 is red on

exposed faces, grayish blue on fractured faces and somewhat porous. No. 2 is a dense specular ore from the same bank.

Nos. 3 and 4 are from the old riverside bank. No. 3 is hard specular ore. No. 4 is a soft hematite.

The following analyses of Simmons mountain ore show the nature of the ores mined in the earlier days of the bank:[1] —

	5 Per cent.	6 Per cent.
Silica	4.12	....
Peroxide of iron	95.24	....
Alumina	0.11	....
Lime	0.33	....
Magnesia	0.15	....
Sulphur	0.00	....
Phosphoric acid	0.052	....
Metallic iron	66.66	61.97
Phosphorus	0.023	0.039

On the outskirts of Salem are two openings in the same ore body, they are known as the Milsap and Orchard banks. Analyses of soft and hard ore from samples representing several hundred tons gave:—

	7 Per cent.	8 Per cent.
Metallic iron	57.96	60.39
Phosphorus	0.067	0.040
Phosphorus ratio	0.116	0.066

It is hardly necessary to add that No. 7 represents a pile of earthy red and blue hematite mixed; while No 6 represents hard blue ore.

Samples taken from the Sligo bank gave the following analyses: —

	9 Per cent.	10 Per cent.
Metallic iron	65.92	65.03
Phosphorus	0.040	0.026
Phosphorus ratio	0.061	0.040

No 9 is mixed hard and soft ore. No. 10 is a greasy variety of hematite known as paint ores.

The following analysis of ore from the Hawkins bank were

[1] From the Report Missouri Geological Survey 1872.

kindly furnished by Mr. C. W. Kalbe, chemist of the Midland Blast Furnace Company:—

	1	2	3
Moisture	9.021	4.659	10.28
Silica	8.28	17.51	8.40
Alumina	2.58	3.96	3.84
Iron (metallic) as received	52.86	49.03	51.35
Iron (metallic) dried 212°	58.10	51.41	57.24
Phosphorus	0.087	0.110	0.123
Phosphorus ratio	0.164	0.224	0.214
Lime	0.87	0.80	0.55
Magnesia	0.457	0.72	0.038
Sulphur	0.123	0.079	0.038
Manganese	.....	.....	0.099

No. 1 is first class ore. No. 2 is second class. No. 3 is a soft purplish ore, very porous.

Phelps County Ores. The two following analyses of iron ores from the Hawkins bank and Meramec bank respectively give: —

	11 Per cent.	12 Per cent.
Metallic iron	56.19	63.28
Phosphorus	0.040	0.050
Phosphorus ratio	0.071	0.079

No. 9 is from the Hawkins bank. No. 10 is from the Meramec bank.

Crawford County Ores. At the time of the taking of the Tenth U. S. Census, Cherry Valley bank No. 2 had not been extensively worked. Since that date this bank has been more fully exploited and has proved to be one of the most extensive deposits in this region. Three partial and one complete analysis of the ore from No. 1 bank are here quoted: —

	13 Per cent.	14 Per cent.	15 Per cent.
Metallic iron	57.18	65.87	58.888
Phosphorus	0.082	0.022	0.085
Phosphorus ratio	0.143	0.033	0.145

No. 11 was taken from the stock pile of the Missouri Furnace Company of St.

Louis; No. 12 specular ore alone; No. 13 is a sample of the soft hematite ore. A complete analysis of No. 14 gives: —

	No. 14 Continued. Per cent.
Metallic iron	65.87
Phosphorus	0.022
Sulphur	0.159
Silica	3.06
Iron protoxide	0.82
Iron peroxide	93.01
Alumina	1.27
Lime	0.28
Magnesia	0.07
Iron disulphide	0.255
Carbonic acid	0.064
Sulphuric acid	0.06
Phosphoric acid	0.051
Carbon in carbonaceous matter	0.02
Hygroscopic water	0.14
Water of composition	0.98
Total	100.056

An analysis of mixed hard and soft hematite from the Scotia bank is here given. Below the workable deposit of ore a bed of pyrite 13 feet thick was found :—

	16 Per cent.	17 Per cent.
Metallic iron	63.10	61.42
Phosphorus	0.063	0.056
Phosphorus ratio	0.091	0.115

Analysis No. 17 is from the McGarry bank near Leasburg.

Franklin County Ores. From Franklin county samples were taken from the Stanton and from the St. Clair banks. The analyses give :—

	18 Per cent.	19 Per cent.	20 Per cent.	21 Per cent.
Metallic iron	[illegible]	57.85	62.40	58.86
Phosphorus	[illegible]	0.072	0.039	0.058
Phosphorus ratio	[illegible]	0.124	0.093	0.099

Nos. 18 and 19 are from the Stanton bank. Nos. 20 and 21 are from the St. Clair bank.

Analyses of ores from the stock piles of the Missouri Furnace Co. of St. Louis representing ore from the Cherry Valley,

McGarry, St. Clair, Handcock, Horse Hollow, Stinson, Stanton, Pomeroy and Lamb banks give the following results:—

	22
	Per cent.
Metallic iron	56.43
Phosphorus	0.065
Phosphorus ratio	0.115

The above analysis is by far the most valuable one, as it represents an actual mixture as used in the furnace. It will be seen that the stock could not be used for Bessemer pig and that the working ore is rather lower than the samples picked from the stock piles at the various mines. As an actual working ore to-day the writer has been told by furnace masters that at Sligo and Midland furnaces an ore far leaner than the above (as low as 45 per cent. metallic iron) is quite often charged in the furnaces. These lower grade ores, it will be remembered though, are smelted on the ground, while the St. Louis furnaces had to take ore shipped for 100 miles or more. The analyses given above go far to uphold, or rather to supplement the statements made in this chapter as to the value of the specular ores of the sandstone region. From a geological stand-point the future of this region is hopeful, while the chemical analyses show that the ores themselves are very desirable.

Grade of ores tually work

CHAPTER VII.

THE LIMONITE ORES.

THE OZARK DISTRICT — THE OSAGE DISTRICT — THE MISSISSIPPI DISTRICT — LIMONITES IN OUTLYING DISTRICTS — THE FORMATION OF LIMONITES — THE VALUE OF THE MISSOURI LIMONITES — CONCLUSIONS.

nites con- d to particu- localities.

Limonite is found in greater or less abundance in nearly every township covered by the members of the Ozark group. It is by no means confined to these rocks, but occurs in rocks of younger formations. It is however on the Cambrian formations that the most numerous and most extensive deposits rest. In this formation there is further a decided choice of position, and this choice appears to be governed by the drainage areas into which the Ozark Uplift is divided as will be shown later on. For convenience in reference, this region will be divided into the following districts: —

I. The Ozark district, on the southeastern slope of the Ozarks. Southeast of a line drawn from township 33 N., 3 E. to township 24 N., 26 W.

II. The Osage district, lying in the valley of the Osage river and its tributaries.

III. The Mississippi district between the Mississippi and Black rivers and south of township 33 N.

Outside of these main districts will be found numerous deposits of limonite, but they are isolated and to a certain extent independent. Such, for example, are the deposits occurring at [illegible], Washington county, at DeSoto, Jefferson county, near [illegible] Francois county, and a few others on the Gas- [illegible]. So far as the [illegible] of the limonites of these [illegible] there is no perceptible difference [illegible] of the one will [illegible] of these belts [illegible] of the Ozark

Uplift is more characteristically developed on the southeastern slope than on the northwestern.

THE OZARK DISTRICT.

Structure of the Ozark Mountains. The topography of the Ozark mountains, so called, is very simple, the whole elevation seeming to be the result of a single fold. The axes of the Uplift run from northeast to southwest, with a minor transverse axis running from northwest to southeast. The minor axis begins a little north of the Missouri river and runs S. 14° E. towards the Mississippi river. The major axis runs at right angles to this, *i.e.*, S. 76° W. The axial crest of this uplift is about 1700 feet above tide level of the Gulf of Mexico.[1] The rocks of this fold, consisting principally of magnesian limestones and of sandstones dip about 1° to the northeast and southeast. This dip turns the water to the southeast and to the north and northeast. Even on such maps of the State as are now extant the axial crest of this uplift is very clearly defined by the courses of the numerous streams. This main divide is very perceptible in traveling over the country.

The Ozarks a single fold practically.

The dips are northwest and southeast.

Development of the Topography. As this region is wholly free from glacial deposits, the secondary topography is due entirely to the rotting of the rocks and to the denuding agency of the streams. The successive steps by which this erosion has been effected appear to have been as follows: The magnesian limestones are generally quite impure. They have a large amount of alumina present in the form of clay. There is also present silica in the form of fine sand, coarse sand and great layers of chert. In the course of time a large part of this lime has been removed by solution leaving the clay, sand and chert in comparatively undisturbed layers. This is the process of disintegration. Through these materials decomposed, or unaltered, the waters soon assume definite courses guided in the rocks either by the original folds or by the more rapid disintegration in one place than another. The continued action along such water courses soon

The limestones are more or less impure.

[1] Level of Cedar Gap on K. C., Ft. S., M. & B. R. R. Communicated by the courtesy of Geo. H. Nettleton, Prest.

excavates numerous gorge-like valleys, between which rise, in the course of time, long ridges or divides, which are winding, sharp crested and narrow at the base. On either side of a stream they rise up steeply, except that where a stream impinges sharply against one bank, thus making a steep rocky bluff, the side opposite the bluff will be low, clayey or loamy, with no rocks in sight.

ams meander m bluff to iff

In addition to the main divides, such as exist between the St. Francis and Black rivers, between the Black and Current rivers and also between the forks of the White river of Arkansas and of Missouri, there are minor divides between the branches of these streams. These minor divides present in general the features of the great central axis and of the divides of the large rivers.

The large divides are what give to the traveler in the Ozark Uplift the impression of mountains. Following the winding roads either in some broad valley, like that at West Plains, or in a narrower valley which is more like a gorge, the steep slopes shut him in on every side. He imagines that by climbing to the summit of the adjoining ridge a broad prospect will be opened up. Having climbed to the summit of one of these hills he finds himself on a narrow ridge or crest line. Lying directly below him on either hand are the streams which have cut the deep gorges. The horizon in every direction shows no loftier peaks or ridges, but everywhere, so far as the eye can reach, are wooded ridges or "Bald Knobs" of nearly uniform elevation. So strong is this resemblance to mountains to the traveler in the valley that he will try many times and experience many disappointments before he can accustom himself to the fact that these ridges and so-called mountains do not rise *above* the level of the surrounding country, but simply that, in the broad reach of ages, these streams have cut *below* the common level, leaving here and there ridges to mark where their former level was. Such, in brief, is the topography of the limonite regions of Missouri.[1]

divides of Ozarks.

s of denu- on.

Locations Favorable for Limonite Deposits. Along the foots of these great divides, and near to the river bottoms,

[1] For further description, see chapter on General Geology.

lie the larger deposits of limonite. Unless the ridge is broad topped with numerous lime-sinks occurring, iron deposits are rarely found on them. If they are found on narrow crested ridges, so far as outside appearances go, they are confined to narrow crevices in limestone rocks or are scattered about on the surfaces of the naked rocks themselves.

High ridges unfavorable for limonite.

The surface appearance of these deposits is nearly or quite the same wherever found. The surface of the ground for an acre or more in extent is largely covered with blocks and angular fragments of limonite. Some of these fragments or boulders weigh many pounds, and some of them many tons. Near Puxico, Chaonia and Leora in Stoddard county, near Alton in Oregon county and Doniphan in Ripley county there are great heaps of boulders that weigh tons each. In such places the ore is apt to be heavily charged with silica in the form of chert, though the percentage of silica is not so high as would be supposed from general appearances. One specimen of this ore from Leora, which was largely mixed with brecciated chert, gave, insoluble matter 16.87 per cent.; metallic iron 50.28 per cent. with phosphorus .047 per cent. Mingled with the fragments of iron ore, on the surface is a great amount of sharp angular chert, with occasional fragments of sandstone. This fragmental sandstone, when present, is dark colored, stained with iron, often with large percentage of iron constituting the cementing material. This superficial layer of chert, sandstone and iron ore is so thick as to completely cover the surface and the only sign of clay or other soil is the sparse growth of oak and hickory, whose roots reach through this stony covering to the underlying soil.

Location of chert ores.

Ores Associated with Limestones. It is very rare that continuously bedded rocks appear to be associated with the limonite iron ore. If such rocks do occur, they are almost invariably limestones. In such instances the distribution of the rocks in a given locality forms almost the only criterion by which one can judge of the extent of the deposit. When the limestones are exposed, they are seen not to be flat and smooth, but to be weathered into ragged surfaces and deep pockets, showing uneven erosion. If the deposit is on the top or near the top of a hill, the limestones are frequently washed bare of the clay mantle which usually

Limestones weather unevenly.

covers them, thus exposing what is judged to be the entire deposit of ore. Yet, even in such cases it is not safe to affirm that the ore body is very limited for an apparently small pocket may expand to a great and unexpected extent. The only probable exception to this rule is when the deposits are almost certainly of limited extent from their very nature. This is when the limonite occurs filling the joints of the limestone which have been enlarged by circulating waters. Here the limonite occurs, growing from the opposite faces of the cleft towards the center and in some cases quite filling it. If the cleft is not entirely filled, the inner faces are usually composed of pyrite or marcasite crystals completely changed to limonite. The inference is that the whole mass was originally a sulphide of iron. These clefts are rarely more than two feet from wall to wall. Occasionally from the banks of brooks such *casts* of limestone clefts will jut out from layers of clay and chert, they representing all that is left of the former limestone. Instances of these deposits will be found near Logans creek, Reynolds county; in township 31 N., 4 W., sections 13, 23 and 24, Shannon county, and on the farm of Judge J. B. Old near Thomasville, Oregon county.

nites occur h limestone.

Ores Imbedded in Clays. There is one other class of deposits of limonite which are found imbedded in clay with no rocks appearing in the immediate vicinity. As has been mentioned before these deposits occur near the foot of the divides or near river bottoms. If they occur on high ground this high ground forms a kind of plateau and is characterized by lime-sinks. The clay enclosing the limonite is of course only the residuary product of the original limestone.

occur in ty clay.

Cedar Bay Mine. Cedar Bay mine, near Piedmont, Wayne county, is a deposit of this kind. It has been worked to some extent and its structure is thus more or less plain. As the bank now is, after about six years of idleness, it is about forty feet from the surface to the bottom of the ore deposit. Twenty feet of the top is stripping, consisting of alternate layers of clay and chert. The clay is sandy and deeply stained with the oxides of iron. The chert is broken into angular fragments of various size and is almost without exception white. The general arrangement is shown in the sketch on the opposite page.

By referring to the figure it will be noticed that the layers of clay and chert are not horizontal, nor in straight lines, but are warped and bent, showing successive settlings, as the lime was removed both from these beds and probably from the limestone beds upon which these rest. About midway from top to bottom in the plate is a large angular block of chert. This lies immediately on top of the ore body which is reported to reach twenty feet below this point. The

Pipe ores of Cedar Bay.

FIG. 48. View of cut at Cedar Bay mine, showing ore body and overlying cherty clay.

ore is of the variety known as "pipe ore." There are a few specimens which show the crystalline forms of pyrite and marcasite. The pipes are of various lengths and nearly at right angles to the overlying layers of clay and chert. There are also shelly grades of limonite, some of which shells are filled with ocher, red clay and sand and some with pure white sand. There is comparatively little solid ore, but there are large masses of brecciated ore consisting of chert fragments connected together by limonite in which the iron bears a large proportion to the

Ore occurs in pipes and concretions.

chert, and the masses are not too lean to be used. At this bank no outcrops of rock are in sight. At the foot of the hill, in
one un-
bed.
the ravine, at the head of which this bank occurs and about one hundred and fifty feet lower, limestone in nearly horizontal layers crops out. On this hill no sandstone is in sight, but on the crests of the hills between this bank and Piedmont, horizontal layers of sandstone are frequent.

Mt. Nebo in Oregon County. On "Mt. Nebo" in Oregon county, township 23 N., 3 W., section 8, are two occurrences of ore which are typical of the two kinds of deposits of which mention has been made. "Mt. Nebo" is a small conical hill as

FIG. 49. Sketch section at Mt. Nebo, showing distribution of fragments of ore over the surface.
At 1 and 2 are shafts 30 ft. deep.

is represented in the above figure, standing about one hundred and fifty feet above the level of the surrounding bottoms. About half way up the slope of the hill begins a surface deposit of iron ore. This deposit covers a belt about one hundred feet wide and reaches nearly around the hill. The deposit is made up of
ter of Mt.
fragments of limonite of various sizes, but no pipe ore is noted. There is an almost equal amount of angular chert and some of this ore encloses chert. At the summit of this hill a shaft about sixteen feet in depth has been sunk. The first six feet consist of layers of broken chert and sandy clay; the remaining ten feet are in limestone, locally known as cotton rock, and the shaft stopped in limestone. This shaft shows very clearly that the core of the hill, not to say the entire body, is of solid limestone. At the foot of the hill is the level bottom of a small stream. Near this point, another shaft about thirty feet in depth has been sunk. This shaft was full of water at the time the locality was visited. The bottom is reported to rest on limestone; the overlying thirty feet consisted, first, of stratified clay and chert for about ten feet, and the remaining twenty feet of clay and chert in which were inbedded lenses and geodes of limonite. This deposit together with others of this nature often met with,

may point out that when scattered fragments of iron lie on the surface of a hill or in close relation to a limestone rock, a larger and more desirable deposit may be found near the foot of the hill where the clay begins to deepen. So few deposits, however, have been even opened that generalizations, except within very safe limits, should not be too sweeping. This will, however, be referred to again.

The Lamons Mine. Of all the deposits of limonite that have been worked there is only one now in operation in the Ozark region, and it is the only one that has been worked in six years. This is the Lamons mine, three and a half miles from West Plains, Mo., owned by the D. Carson Iron Company. Here, there has mined and shipped from 1889 to June 1st, 1891, 8,000 tons of ore to the Argentine silver lead smelters at Kansas City. In mining this ore a great deal of work has been done in development, and it is the only bank which has been accessible for close observation below the surface. It is believed to be a fair type of the great majority of the deposits of the Ozark district.

Limonite used as a flux.

FIG. 50. A general view of Lamons iron mine, looking southeastwards.

Fig. 50 gives a general view of the bank looking southeastwards. In the foreground, between the opening and the fence runs a brook. The level meadow reaches back nearly one half of a mile to another chert covered hill. The highest point of this hill, near the house, a little to the right of the middle of the picture is about one hundred feet above the level of the meadow.

Description of figure.

In the foreground, near the fence, there are no indications of iron; in the field, back of this, for one thousand feet there are very fair showings of iron. The width of this belt varies from three to five hundred feet. At the end of this one thou-

er of ...'s bank.

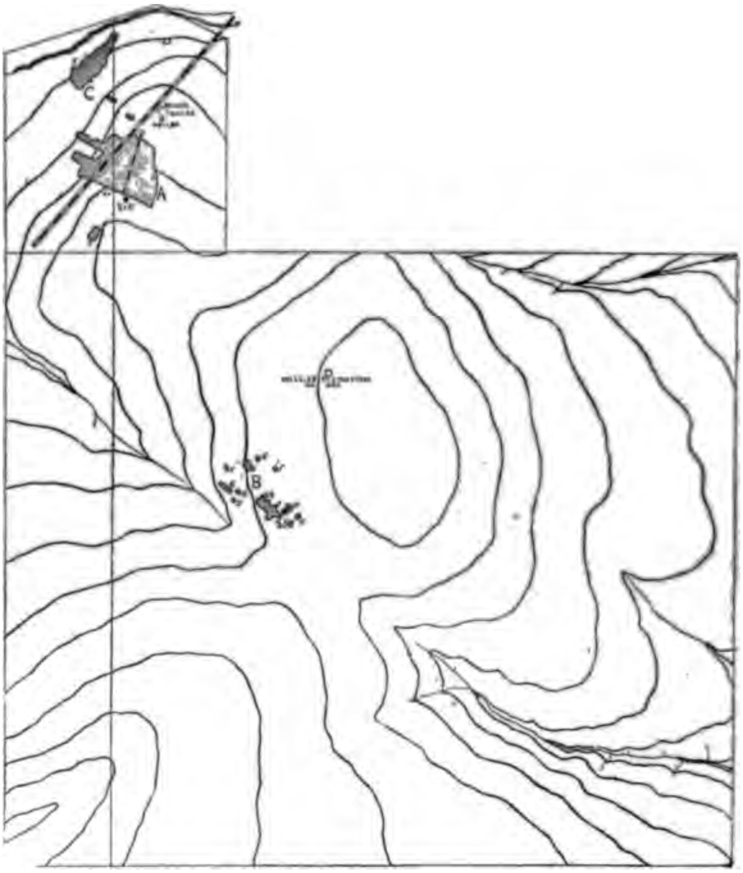

FIG. 51. A topographic sketch map of Lamons iron mine.
A is the main mine.
B are surface diggings.
S S are shafts.
The figures denote depth at the different points.

sand foot line the hill slopes down to another, but narrower valley. To the right this hill, which is really but a spur, joins a much larger hill or divide. The surface of this hill differs in no material respect from that at hundreds of other deposits which are found in the limonite region. There are no surface

...phy of a ...on form.

rocks anywhere in sight. The hill is covered with sharp chert fragments and some large angular blocks. In the belt this chert is intimately mixed with ore fragments.

On the topographic sketch, on page 166, made by Mr. E. H. Lonsdale of the Survey staff, the different openings have been accurately located, and the location of the ore body can be seen with reference to both the hill and the more level ground at the railroad tracks. Topographic map of the Lamons bank.

As was before mentioned, the recent working of this mine or bank gives the third dimension which is so rarely seen in this field.[1] At the foot of the large oak at the right of the horse-whim (see Fig. 50) several pits have been dug five or ten feet in depth. These pits have all struck solid brown ore of a very fine quality. In the soil above, which is cherty and deeply stained with iron, are very numerous fragments of hard limonite ore.

FIG. 52. Sketch from a photograph of the southwest wall of Lamons ore bank, showing the face of ore under the overlying soil.

Fig. 52 shows a part of the main opening. The view is taken looking southeastwards. The pole standing up against the wall is fourteen feet long. From the surface of the ground to about the middle of the pole, a distance of twenty feet, is soil and iron ore in the following order: From the surface towards the top of Sectional description.

[1] Letter A on the topographic map shows the position of this ore body relatively to the hill.

the pole, in a sandy clay mingled with angular flint are rounded and angular fragments of limonite of various sizes. Under this layer, which is about four feet thick, is a distinct bed, ten feet thick, consisting of stratified clay, angular chert, and fragments of limonite. Lower down, the last six feet is seamy clay, gritty and carrying much decomposed chert and large masses of limonite in thin, hard lenticular layers, which also inclose much dirt. The clay varies in color, being at times yellowish white, brick red and then in bands mixed with much ocher.[1] The next layer, downwards begins at the middle point of the pole and is a layer four feet thick of solid limonite. By solid is meant that the bed is continuous and compact, with occasional irregular ocherous joints, but is so compact and solid, that, if it were desirable to mine the underlying ore instead of stripping it, this bed, with comparative light timbering would make a good roof.

Description of section.

Immediately under this is a bed, three feet thick, of lamellar, loose, ocherous, dirty ore and then a one-foot layer of flint of lenticular shape. Below this there begins another bed of nearly sölid ore, about twenty feet in thickness. This is the limit of the workings at present. No explorations have been made below this point. This last solid bed of ore has numerous lenses of flint or chert of rather limited dimensions. There are also lenses of bright red clay and nearly white clay. The bottom of the ore body has not been reached.

Continued.

The ore body, as developed by the workings, then, is as follows, beginning at the surface:—

Layer 1. 20 ft. stratified clay and chert with little iron, whole body worthless.
" 2. 4 " of solid limonite ore.
" 3. 3 " loose, lamellar, ocherous ore.
" 4. 1 foot chert.
" 5. 20 feet alternate beds of solid limonite and layers of chert and clay. This latter is given on the authority of Mr. Carson as the lower part of the mine was full of water.

[1] This last six feet is worked as an ore in spite of the clay seams. The dividing line between the ore body proper and the overlying "stripping" of dirt begins at the line between the dark and light shading. The detail pointed out above does not show in the figure. There are only two bands prominent as one looks at the bank: First the sandy clayey soil with dark stringers of ore; and second the dark ore body consisting principally of limonite.

The whole face of ore proved by these workings is 28 feet deep; length from east to west 230 feet; and length north and south not certainly known. With regard to this length, however, the following facts will give some light. Five hundred feet towards the southeast numerous openings have been made but none of them very deep.[1] These openings show the same ore as it is found at the large cut. There is, however, this difference. Boulders are found almost immediately below the surface and the solid ore is reached nearer the surface. Near the apex of the hill on which the ore body is located, by the little house, a well sixty feet in depth was dug. The location of this well is shown in Fig. 51. Little or no ore was found in this well and the bottom is limestone. It is probable, therefore, that the ore body does not extend east of this. Near the scale house, shown on the map, east of the main opening, a bored well eighty feet deep was sunk. Forty feet of this is reported to have gone through chert and clay with a little iron and the last sixteen feet was in nearly solid limonite. No record was kept of this well, and the memory of the well borer is the source of information.

Depth of ore.

The principal conclusions from this mine, and they are of great importance, are that these surface deposits of limonite, showing mingled fragments of chert and ocherous clay, with no rocks in sight, and especially when on *low, flat* hills may turn out to be very respectable deposits as to size.

If the full width of the mine, as developed, be taken (230 ft.) and the depths (28 ft.) be reduced by one half, and the length (500 ft.) be also reduced by one half, we have the total contents of the mine as follows: 230x14x250=905,000 cubic feet. Allowing fifteen cubic feet to the ton (this allowance including impurities and foreign matter associated with the ore) there are here 60,333 tons of workable ore. This certainly is a conservative estimate, and though not the result of careful surveys, it will point out what evidently lies in sight from the showing of the present workings.

Dimensions of bank.

With regard to the quality of the ore, it is a high grade limonite. In addition to the numerous analyses furnished by the courtesy of

[1] See B. of Fig. 51.

Mr. Carson, samples were collected personally and analyzed for the Survey by the St. Louis Sampling and Testing Works. The analyses of the ore showed a considerable range in phosphorus. To determine whether the phosphorus was confined to any one particular kind of ore two samples were collected from strata as follows. No. 1 was very carefully selected from the most compact ore in the stratum exposed and great care was exercised to have the specimens free from ocher or dirt. No. 2 was collected from the same strata, but in this case the loose porous part of the solid strata was taken together with a part of the ocherous filling.

ality of ore.

	No. 1. Compact Ore.	No. 2. Loose Ore.
Loss by ignition	11.57 per cent.	12.21 per cent.
Silica	2.11 "	4.68 "
Sesquioxide of iron	86.27 "	82.75 "
Alumina	0.03 "	0.13 "
Sulphur	0.103 "	0.060 "
Phosphorus	0.076 "	0.132 "
Metallic iron	60.39 "	57.92 "

Although the result was not wholly what was hoped for, it shows that the most compact ore carries the least phosphorus, and that in many of these deposits there may be found Bessemer ores. That even in the same deposit there is sometimes a yet wider variation, the two following analyses of samples collected by Mr. Carson, fully shows:—

nalyses.

Silica	3.65	9.75
Sesquioxide of iron	82.40	73.60
Sulphur	0.112	0.058
Phosphorus	0.028	0.399
Loss by ignition	12.84	14.02
Metallic iron	57.68	51.52

Sulphur tends to increase with depths.

In this bank as in many others where there has been an opportunity for examination, there seems to be a tendency towards an increase in sulphur with increasing depths, or at least when the bottom of the deposit has been reached, or is supposed to have been reached. This subject will, however, be better discussed later.

Other Banks in the Vicinity of West Plains. In township 24 N., 7 W., section 24, three shafts have been sunk, each about fifty

feet deep on an outcrop very similar to that at the Lamons bank. Two of these pits yielded a moderate amount of siliceous and sulphurous ore. The ore does not seem to exist in any great bulk, but to be evenly and sparsely scattered through a highly stained sandy clay. The main body of the ore may not have been reached.

In township 23 N., 1 W., section 7, there have also been several test pits dug. One of these pits is forty feet deep. The first eighteen feet is chert and fragments of iron in a sandy red clay. There are also lenticular layers of white, chalky looking decomposed chert. Then comes four feet of solid limonite, followed by eighteen feet of porous limonite which is very free from silica. When work ceased the bottom of the ore body had not been reached. The pit was inaccessible when visited and the above was reported by Mr. Carson. The material taken from this pit was at the mouth and the ore was examined. Sections of other banks.

Numerous other localities were examined in the vicinity of West Plains. All showed the same general surface appearances and, where test holes had been dug, the same general character was shown.

It is especially to be noted that a most common character of the surface ores of these deposits is that they are nearly all pseudomorph after pyrite or marcasite. In many cases the crystalline form was easily indentified as cubes with the octahedral faces largely developed. In other cases the crystalline form of marcasite was represented. In the main body of the deposits, from four feet or more below the surface, the ore is generally very compact and shows no trace of pseudomorphism. There are layers of sulphurous ore, but they are comparatively infrequent until near the bottom of the mine. Ores are often pseudomorphous.

The J. B. Old Bank. There is another bank, typical of another class of deposits, which, though not so numerous as the last are yet highly interesting and instructive. This class of deposits is far more extensive in the Osage district than in either the Mississippi or the Ozark district. It is very doubtful if another bank showing the structure and origin so perfectly exists.

This bank is the property of Hon. J. B. Old, of Thomasville, Oregon county, and is four miles from Thomasville, up the

Eleven Point river. On either side of the river, are hills of limestone capped with sandstone, which are about three hundred feet high. The river shifts from side to side of a bottom about fifteen hundred feet wide. From the top of the divide there run numerous narrow gorges, cut by streams which empty into the river. One of these gorges looking north is shown in Fig. 53.

Location of the Old bank.

FIG. 53. View of gorge in which the Olds iron bank is located.

In this figure it will be noticed that the limestone in the hill is horizontal, and it is evident that the gorge as well the river bed is the result of erosion. The ore bed is situated in this gorge on the east side and about a hundred feet from the mouth. The ore body juts out from the side of the gorge, as is shown in Fig. 54, and is seen to be made up of stalactites of iron about one-half of an inch in diameter. These stalactites are vertical now, save for the numerous large masses which have broken off and are lying about. This ore body does not show on the opposite bank, near the bottom of the gorge, though the rocks are entirely hidden by boulders of iron ore, sandstone, limonite and chert which have rolled down from above which would hide the ore body even if it extended across the ravine. The extent downward of the ore is also unknown. A cross section of the gorge and ore body is given in Fig. 55. The dimensions are 100 ft. by 100 ft. by 10 ft. That is, the bank of solid ore exposed is one hundred feet wide, ten feet high and reaches toward the hill on its upper surface, one hundred feet. This is probably not the limit of size, but

Stalactitic nature of the ore.

this much stands out clearly. There are, therefore, 100,000 cubic feet of ore in sight. Allowing twelve cubic feet to a long ton, there are over 8,000 tons of ore in sight. The excellence

Amount of ore in sight.

FIG. 54. View of stalactitic ore body at the Olds Bank.

of this kind of ore can be judged from the following analysis of an average sample made for the Geological Survey by the St. Louis Sampling and Testing Works: —

Moisture	12.16	per cent.
Silica	2.49	"
Alumina	0.78	"
Sesquioxide of iron	84.32	"
Sulphur	0.066	"
Phosphorus	0.077	"
Metallic iron	59.02	"

FIG. 55. A cross section at the Olds Bank.

J. N. Hains' Bank. As was before remarked, stalactitic ores are somewhat rare in the Ozark district. There is another locality, however, which presents a good showing of this kind of ore, although not so perfect as that of the Old bank. J. N.

Hains bank similar to the above.

Hains' bank, near Alton, Oregon county (township 24 N., 4 W., Sec. 34), shows beautiful specimens of stalactite ore. The surface of the ground for nearly an acre is thickly strewn with "pipes" of limonite. Solid masses when broken in two, show that they are geodes with the inside filled with pipes, as is illustrated in Fig. 56. There is very little rock on the surface of the ground at this point and chert is only slightly mixed with the ore. There have been several test pits no more than five or ten feet in depth, dug at this place, and all show an abundance of pipe ore in a red clay.


FIG. 56. A stalactite geode of limonite.

Other Localities in the Ozark District. There are pipe ores to be found on the Current River railway near Spur Five, west of McDonald, on the St. Francis river near Chaonia; on the St. Louis, Cape Girardeau and Fort Smith railway at Indian Ford, and also on the Iron Mountain road in Wayne county, near Piedmont and Mill Springs and also near Williamsville. Several of these localities in the vicinity of Piedmont and Mill Spring have been worked slightly and have yielded excellent ores of their class. All work has ceased here now, however.

Stalactitic [deposi]its.

THE OSAGE DISTRICT.

General Distribution and Character of the Ores. The limonites of the Osage district appear to differ very essentially in one respect from the ores of the Ozark district. Nearly all of the latter ores are stalactitic. The limonites of the Ozark belt may yet prove to be stalactitic to a greater extent than is apparent where openings have been made; but at present the Osage limonites are richer and purer on account of their form, for it is very evident that a stalactite ore would be higher grade than ores falling to the bottom of a cave reservoir and mixed with dirt washed in or falling from the roof of a cave.

Limonites [gener]ally richer.

The ores of this district are confined principally to Franklin, Osage, Morgan, Benton, Miller, Camden, Hickory and St. Clair counties. The deposits of the lower Osage near the Missouri are comparatively of little account. At the extreme upper part

of the Osage in Missouri, in the prairie counties, the same is true. The main iron bearing district of this field is then, the Middle Osage region. Towards the southeast the limonites appear to be more closely connected with the specular hematites, while towards Henry county, and in the south of Benton county the red hematites occur with the limonites. Location of Osage deposits.

To show the excellence of these ores, the following analyses are copied from the report of the "Geological Survey of Missouri, 1872, Part I, p. 43. These analyses were made from large samples sent in by owners of banks and from samples collected by Dr. Schmidt or under his direction. They can safely be assumed to be fairly representative of the ores of this region.

Analyses of Osage ores.

	1	2	3	4	5	6	7	8	9	10
Insoluble	....	....	....	....	....	8.66	7.17	7.42	8.85	4.88
Peroxide of iron	84.02	77.42	82.02	....	84.10	81.96	73.78	79.82	79.53	82.27
Water..	10.98	12.49	12.80	....	11.60	....	....	....	....	....
Sulphur.	0.171	0.147	0.015	0.084	none	none	none	0.009	tr.	trace
Phosphoric acid..	0.861	0.076	0.091	0.084	0.077	....	....	....	....	....
Silica...	3.08	8.05	5.13	....	3.59	....	....	....	....	....
Metallic iron..	58.81	54.19	57.41	....	58.87	57.39	55.11	55.87	55.67	57.59
Phosphorus...	0.376	0.034	0.041	0.037	0.034	0.058	0.081	0.061	0.071	0.074

1. Brown and red hematite, Marmaduke bank.
2. Limonite, Sheldon bank.
3. Limonite, White bank.
4. Limonite (pipe ore), Elm Hollow bank.
5. Limonite (pipe ore), Indian creek bank.

6, 7, 8, 9 and 10 are all from Camden county.

From the above analyses it will be seen that numbers 2, 3, 4, 5 and 6 are not available for the manufacture of Bessemer pig; though they as well as the others would be available for the manufacture of a high grade of either merchant or foundry iron. Value of these ores.

Deficient Transportation Facilities. The same conditions which have prevented the development of the iron ores of the Ozark district are present in the Osage district also. There are

even fewer railroad facilities. A narrow gauge road runs from Sedalia to Warsaw. This road, however, goes up to the iron belt without in reality entering it and it will with difficulty be available for transportation. It runs at right angles to the district and not parallel to it. A standard gauge road connects Tipton with Versailles, in Morgan county. But this road is even less available than the one from Warsaw to Sedalia. The natural outlet is by the Osage and Missouri rivers. But these streams are so fluctuating, that they also are practically unavailable for steady traffic unless they be improved.[1]

of transport-n.

THE MISSISSIPPI RIVER DISTRICT.

General Distribution of Ores. The ores of the Mississippi river district are, as stated by Dr. Schmidt, largely stalactitic, at least the ore of the bodies which have been mined. The localities where iron has been mined are Irondale, De Soto, Marble Hill and Cornwall. In addition there are other isolated localities where mines have been operated more or less. The Cedar Bay mine, near Piedmont, and several mines near Mill Spring have yielded stalactite ore. These mines, however, have shown very little chert ore, such as found in Stoddard county. The iron ores near Puxico, Leora and Casterville appear to be quite different from the above, both on account of the chert which they carry mingled with the ore, and from the fact that stalactitic structure is not common.

of the Mis-sippi district.

Ores near Puxico. As has already been mentioned, at Puxico and Leora there are great ridges or banks of limonite in which are imbedded numerous angular fragments of chert; there is also much alumina and fine sand. In several localities near Puxico pits have been dug and trenches have been cut across the banks. All of these diggings have shown the same condition of things: *i. e* , an abundance of cherty limonite. Fig. 57 shows the large blocks of cherty ore exposed on the surface here. No stalactites

lopment r Puxico.

[1] In Chapter X of Part II, in the latter part of this volume, descriptions of the various ore deposits of the Osage district are given. These are largely extracted from Dr. Schmidt's report, because few or no developments have been made since that time, and nothing more can be seen. — A. W.

were found in these deposits, though it must be said that no thorough exploration was made. It may be possible that a more thorough examination will show either stalactitic ore, or at least solid ore with lower silica and a higher percentage of metallic iron. But even if such exploration fails to make a better show-

Nature of deposits at Puxico.

FIG. 57. View showing manner of occurrence of large surface boulders of cherty ore near Puxico.

ing, the present surface indications point to numerous and extensive deposits, which are available, under certain circumstances, as the following analyses made for the Geological Survey by the St. Louis Sampling and Testing Works prove:—

	Chaonia ore.	Leora ore.	Mill Spring ore.
Insoluble matter	15.60	16.87	5.91
Metallic iron	49.91	50.28	56.47
Phosphorus	0.109	0.047	0.135
Sulphur	0.104	0.138	undeterm.

Analyses.

The first two were both cherty ores with no stalactites and were collected by the writer from at least one hundred boulders lying on the surface. The samples were selected with great care, the object being to determine whether these ore bodies rose too high

in silica to be available. The results seem to indicate that under favorable circumstances even these most unpromising chert ores will make iron profitably.

Mr. Moore's descriptions.

Descriptions by P. N. Moore. In the Report of the Geological Survey of Missouri Field Work, 1873, 1874, p. 638. Mr. P. N. Moore gives a somewhat extended notice of iron ores in this section. Some of the deposits which he notes were worked about this time (1873–1874), and the data which he there gives is very instructive. A series of analyses of iron ores collected by him bear out the conclusions drawn from the above analyses: —

Analyses of other deposits.

	1	2	3	4	5	6	7		9
Water	11.43	8.92	10.38	8.99	10.97	6.72	8.50	8.57	9.38
Insoluble matter	7.46	33.97	14.72	15.29	17.19	42.25	16.46	25.97	25.58
Peroxide of iron	79.57	53.87	74.37	74.87	70.43	50.01	74.71	64.18	63.25
Sulphur	0.017	trace	none	0.037	none	trace	0.016	0.003	trace
Phosphoric acid	0.328	0.143	none	0.154	0.130	0.096	0.164	0.153	0.147
Metallic iron	55.70	37.36	52.06	52.41	49.30	35.01	52.30	44.93	44.27
Phosphorus	0.141	0.062	none	0.067	0.057	0.042	0.071	0.066	0.064

No. 1 is from the Nifong bank, township 31 N. 5 E., sec. 2.
No. 2 " " " Green Emma bank, township 30 N. 9 E. sec. 16.
No. 3 " " " Myers bank, township 32 N. 5 E. sec. 32.
No. 4 " " " Bear Mt. bank, township 34 N. 3 E. sec. 2.
No. 5 [illegible] township 27 N. [illegible] E. sec. 28.
No. 6 [illegible] township 28 N. [illegible] E. sec. 16.
No. 7 [illegible] township 28 N. [illegible] E. sec. 16.
No. 8 [illegible] township 27 N. [illegible] E. sec. 15.
No. 9 [illegible] township 2? N. 7 E. sec. 24.

[illegible] are samples of the ordinary cherty [illegible] samples of the dark colored reddish [illegible] to hematite. [illegible] No. [illegible] is essentially [illegible] and streak, they [illegible] the same amount [illegible] No. 5 is a [illegible] sand instead [illegible]

[illegible] district banks [illegible] In the Iron [illegible] has been done for [illegible]

nearly twenty years and only the following data could be observed.

There are two circular excavations from which a good deal of lean cherty ore has been taken. A shaft was sunk to the depth of thirty feet and a tunnel was driven from near the foot of the hill to meet it as is represented in the cross-section, Fig. 58. Shaft and tunnel excavated.

FIG. 58. Section through Hendrickson mine.

The tunnel, which was reported to be one hundred feet in length, ran through colored clays, loose chert and small seams or streaks of cherty ore. The tunnel did not strike any considerable deposit of ore. The shaft, although badly fallen in, yet showed that the material lying on the hill was stratified, probably the residuary clays and chert and sand of the original limestone. As nearly as could be observed a vertical section would show as follows:—

1st. The surface of the hill is covered with a cherty limestone.

2nd. Beneath the surface are boulders of cherty limonite, with interstitial highly colored clay. Section of Hendrickson bank.

3rd. Chert in layers in a stratiform red clay.

4th. Fair limonite mixed with chert and clay, not connected.

5th. Cherty iron ore.

This ends the direct knowledge of the shaft, as the remainder had fallen in. Enough was seen, however, to show that this particular deposit differed from the Lamons bank, near West Plains, in that the percentage of metallic iron is very much lower, the silica much higher, and that the deposit is not as extensive. There are no bedded rocks to be seen on the surface of the hill, which is covered with cherty soil and irregular blocks of sandstone of small size. In the bed of a small brook at the south end of this hill bedded limestone shows, so it is probable that the above deposit at Hendrickson is on limestone as usual (see Fig. 58). No bedded rocks to be seen.

This deposit is marked on Schmidt's map (Preliminary Map showing the Distribution of the Iron Ores of Missouri, 1873)

as a "drifted" deposit of specular iron ore. The work that has been done there shows that it certainly is not drifted. As to its being specular ore, Mr. P. N. Moore,[1] writes as follows: "Much of it" (the ore of this bank) "is red and gives a red streak and in its luster and fracture appears like specular ore, but that it is not so is proved by the fact of its containing combined water. It is this ore which has given to the bank the name of a specular ore deposit, and it was recorded as such in the Geological Report for 1872. Specimens of this ore showing stalactites and botryoidal forms, are often found adhering and passing insensibly into brown ocherous limonite. These stalactites show every appearance of specular ore, but on analyses by Mr. Chauvenet they were found to contain 9.39 per cent. of water, thus proving the ore to be very nearly a true limonite. Much of this ore which appears red will give a brown streak upon porcelain, showing at once, and without further examination, that it is limonite."

...idal nature ...ore.

It seems a little strange if Dr. Schmidt put this deposit down as specular iron unless some specular ore was actually found, for there is hardly a limonite deposit in which many of the above recorded phenomena may not be observed, and Dr. Schmidt is generally very careful in distinguishing between *red hematite* and *specular iron ore*.

However this may be, the mineral "having the appearance of specular ore, only containing water" is more than likely turgite. Dana's description of turgite is: "Color reddish black to dark red, bright red when earthy; botryoidal surface often lustrous, like much limonite; streak red. Opaque." According to Dana, the water in this mineral reaches only 5.64 per cent. This mineral, says Dana, is a very common ore of iron, often taken for limonite, with which it is frequently associated, and which it resembles, except in its superior hardness, streak and decrepitation. It also looks very much like fibrous limonite. The analyses that Mr. Moore quotes show this mineral (at the Black river mine) to contain 9.38 per cent. of water, and he therefore concludes that the mineral is limonite. It is entirely

...ly derived ...specular

[1] "Report of the Geological Survey of Missouri," 1873 and 1874, p. 660.

probable that this red mineral is changing to limonite by a process of hydration, and it can as well have come originally from specular ore as from any other source. In fact he (Mr. Moore) says that the stalactites and botryoidal masses show every appearance of specular ore. The fact also that this material is found "passing insensibly into true brown ocherous limonite" strengthens this supposition. It shows probably that the mineral turgite is passing into limonite, and the specimen analyzed, containing too much water for turgite and too little for limonite, may mean one of two things. First, that the specimen was in part turgite and in part limonite; or second, that the specular ore by hydration was passing into limonite.

Limonite common in specular ore regions.

In the specular ore regions of Missouri it is very common to find specimens of limonite which, in the same block towards the center, passes into specular ore by a perfect shading. In other words, the outside of the block may be a pure limonite while the inside is a pure specular ore. Taking these facts into consideration, and another fact, *i. e.*, that isolated specular ore deposits are found in this region, it is hardly too much to assume that this is a deposit of partially changed specular ore.

LIMONITES IN OUTLYING DISTRICTS.

Outlying deposits exhausted.

In giving the outlines or boundaries of the three great limonite districts of Missouri, there are, as was stated, many isolated localities which do not readily fall into any of the broader general divisions. Some of these localities like Irondale, De Soto, Iron Hill, Moselle, Cornwall, etc., belong to the same general formation, viz., the Ozark series of the Ozark mountains, and have in time past yielded considerable amounts of ore. But these localities appear to be pretty well exhausted and there seems to be no other promising surface indications near by. There is no need of giving these localities more than a passing notice for they are in structure, variety and relation to surrounding rocks, identical with the iron ores occurring in the main districts which have already been noted at length.

In the great "Central Region of Specular Ore" there are many limonite deposits occurring, but many of these on being

developed grade into the blue ore of this region. Strictly speaking they should not be classed as limonite ore deposits, but should be treated under the head of specular iron ores. The same may be said of the deposits of limonite found in Callaway and Henry counties in connection with the bedded deposits of red hematite. There are, however, in the carboniferous formations which surround the Ozark uplift, many deposits of limonite which ought to be mentioned, though none have yet been found extensive or rich enough to work.

Near Fray's Mill, seven miles from Huntsville, Randolph county, is one of the deposits referred to. This is located on the East Fork of the Chariton river (see Fig. 59). The rocks around belong to the Coal Measures, as is abundantly proved by fossil coal plants in the rocks and associated coal beds. Sections from shafts and from cuts along roads show, first, a porous sandstone highly colored with iron; second, clay shales imperfectly hardened, and, third, a bed of impure limestone. It will be seen that the conditions are thus favorable for the formation of small deposits of bog iron ore. The ferruginous sandstones lying above, freely allow water carrying organic matter to percolate through them, while the shales and limestones, impervious to water, hold the water in the form of springs or bogs, until the iron, held in solution, is re-oxidized and precipitated in the form of bog iron ore.

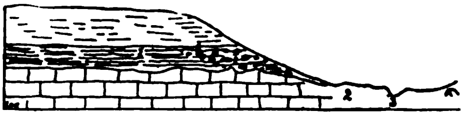

FIG. 59. Section at Fray's Mill.
1 is Bog Ore on limestone.
2 is Alluvium.
3 is the creek.

The cut, Fig. 59, shows this to be true in the particular locality of Fray's mill. As indicated here, the river has a broad bottom of alluvium of unknown depth. Above the bottom and in the middle of the public road, the iron ore crops out as shown. The outcropping of both shale and limestone under the deposit shows it to be of limited extent virtually. A gulley, cut through the adjoining fields by a stream, and a well dug to the depth of

twenty feet fail to show any trace of this ore. This goes to prove conclusively the limited lateral extent of the deposit.

Some considerable interest has been aroused on account of the appearance of similar deposits in other localities on this stream and this has led to the hope that these may be the indices of a greater but so far hidden deposit. But if it is borne in mind that the country around is comparatively flat, and the rocks horizontal, and that this river has cut its channel under such conditions, the reason for this extent will become apparent. The river cutting through the sandstone and, in many cases, through the shale and into the limestone, has given an opportunity for water percolating through the ferruginous sandstone to emerge with its burden of iron at or near the banks of the river. Here the water, though in places flowing immediately into the river, has elsewhere been hindered long enough to have its iron oxidized and precipitated. Under the existing conditions, it is highly improbable that an extensive deposit has been formed, however favorable surface indications may be.

Explanation of the origin of these deposits.

The iron ore is hardly rich enough to warrant extensive explorations, although this is the only means to exactly determine the extent. No complete analysis was made, but 49 per cent. of metallic iron was found in a few specimens collected by the Survey.

At Clinton, Henry County. Another deposit of similar nature, in Clinton, Henry county, Mo., was called to our attention by Dr. Britts of that city. The deposit is situated on the brow of a hill overlooking a narrow valley or rather gully below. A ferruginous sandstone and underlying shale is observable, but no limestone is in sight. It will be seen that the conditions here are almost identical with those at the last named locality, at Fray's mill. The rocks are of Coal Measure age. There is comparatively little sand in the ore, but there appears to be a great deal of alumina present. The deposit in the thickest part is not over four feet and rapidly thins out towards the edges. The iron is bog iron and was evidently formed in a small basin shaped pool.

Spring deposit at Clinton.

At Browningion. One mile east of Brownington is Stewarts bank. Attention was also called to this by Dr. Britts. At first

ownington. sight this locality looks very promising, but an examination of the ore shows it to be full of sand. There are only a few pieces free from silica. Several holes have been dug five to ten feet in depth, but no change for the better was found. In many localities around this place are exposures of a highly ferruginous sandstone. These are so highly colored as to have the appearance of iron ore, and there are, no doubt, many places where the metallic iron is in excess of the silica. But it must be borne in mind that these are more after the nature of segregations than regular bedded deposits, and it is thus extremely doubtful if any extensive deposits will be found.

In Dade County, township 30 N., 25 W., section 35, is a peculiar deposit on the farm of Mr. G. A. Compton. This deposit is peculiar since it has much fibrous limonite or turgite, and the ores also occur in large shells or bombs. It closely resembles the Salisbury, Conn., ore. The surface of the field in which it occurs is strewn with half-buried fragments. In the bed of a brook near the field were exposed many boulders of excellent ore which had been washed from the banks. In the road, where it crossed the bank, were piled a large number of boulders, also of iron, which had been picked from the field.

There are here occasional outcrops of a dark red sandstone impregnated with iron. There were no outcrops near the field in which the iron occurred, neither did the shafts which were sunk in this field penetrate the sandstone, so the relations between the clays and iron ore cannot be made out at present. Twelve years ago a shaft fifty-three feet deep was dug here to determine the amount of ore. The result appears to have been unfavorable since nothing has been done since. The hole has so fallen in that the only data to be gained was from the debris around the mouth of the shaft. This consisted of red clay, chert and large fragments of very pure iron ore. A test pit recently dug fifteen feet in depth showed that chert occurred here in layers in a red clay and that the iron ore lay in irregular nodules in the clay and partially in the chert. The chert is fossiliferous and there are also fossils in the more porous iron ore. The fossils found were crinoid stems. This deposit is

re of the le Co. limtes.

unique in that its ore is principally fibrous with occasionally highly polished surfaces: it resembles the limonites of the Ozark region in that it occurs in a stratified clay with broken chert. The ore is free from chert in the mass, and is free from sand, while the Ozark limonites are cherty and often sandy. This ore has a clean dark brown color; while the others are dull and earthy. These ores are found in rocks of Lower Carboniferous age while the others are confined to the Ozark series.

General Conclusions. Whether any extensive ore deposits will be found in this geological horizon or not it is hard to say. In many respects as has been pointed out, the conditions are similar to those of the Ozark district, both the Ozark limonites and these being associated with the decomposition of limestone. But in the Ozark region the deposits of iron ore are uncovered by streams or the soil has been washed from them by rains. In this region there are streams and there are hills. Yet neither in the bed of the streams nor on the slopes of hills are there exposures of iron comparing in size and number with those of the iron ore belts of the Ozark. There is but one conclusion to be drawn and that is that the deposits of iron here are not so abundant. If there are any extensive deposits they will have to be reached by exploration underground, for they give few favorable signs on the surface.

Outlying deposits not promising.

THE FORMATION OF LIMONITES.

We have now described, with some fullness, the character and conditions of occurrence of the limonites of the State. A discussion of the mode of formation of these ores, based upon these observed facts, will hence be in place here.

In order to understand the relationship between the peculiar topography of the Ozark mountains and the limonites so abundantly found in them, it may be well to briefly review the probable sources of limonite and the manner in which it is collected in large deposits. In the etymology of the word "limonite" there is a very compact explanation of its origin, and we have but to expand the ideas contained in order to have the relationship above referred to clearly outlined.

Relation of ores to topography.

nites never ginal constituents.

The Secondary Growth of Limonites. Limonites are always of secondary origin. By this is meant that they never occur as original constituents of either primitive or eruptive rocks as do magnetites, hematites, and, in fact, many other anhydrous minerals. They may form directly or indirectly in the following ways:

t origin of onites.

The process of limonite formation by what may be called the direct way is very simple. Limonite may be derived directly from magnetite or from hematite. Let us imagine a rock impregnated with grains or crystals of either magnetite or hematite. Both of these minerals are anhydrous oxides of iron, and they are what are known to chemists as unstable compounds. If these minerals be exposed to the action of even pure water, either as a liquid or as vapor from the air, there is a tendency for them to unite with a certain amount of water chemically and to form an entirely different mineral. This mineral is limonite or hydrous oxide of iron. In this process of hydration there is an entire loss of the original physical characteristics. The cherry red of the hematite and the dense black of the magnetite is changed for the earthy brown of the limonite. The mineral increases in bulk and loses in specific gravity. All this may take place without altering the original shape of the grains or crystals of either the hematite or magnetite. This process may be called hydration and is apt to affect the rock containing the iron as well as the iron itself. Expanding this idea, it will be readily seen that, if the hematite or magnetite exists in large deposits in the original rocks, these large deposits may pass directly, by hydration, into beds of limonite occupying exactly the same position as before.

ples.

As an illustration of this, it may be stated that in New Jersey and in Pennsylvania, and in other regions where beds of hematite and magnetite occur below the line of glacial action, mining operations are oftentimes begun on outcrops of limonite and, as the mines become deeper, the ore gradually changes to hematite or to magnetite of the case may be. It is also noticed, in the specular ore regions of Missouri, both in the porphyry and sandstone regions, that the outcropping ore is limonite, and, even at considerable depths, the blocks of specular ore are coated with

limonite. If the deposits are small they may be wholly changed to this mineral. By this direct method, then, it is evident that a deposit of iron, either magnetite or hematite originally, may have changed its physical characteristics without altering its position. By the indirect method this is impossible.

Character of or may change.

Magnetite, hematite, and limonite are wholly insoluble in pure water. Iron in the protoxide state is, however, readily soluble. All that is necessary, therefore, to make any oxide of iron soluble is to reduce it to the protoxide form. Organic matter is one of the most powerful of reducing agents. Organic matter, largely composed of carbon, coming in contact with the above named minerals, takes their oxygen from them, reducing them to the protoxide state, thus making them readily soluble in water containing a little carbon dioxide. In this form the iron may be carried wherever the water goes and the water only gives up its iron as the latter becomes re-oxidized, when it is at once precipitated. This reoxidation may occur in a number of ways. If the water, carrying iron in solution, percolates through rocks and drips from the roofs of caverns it becomes thoroughly aerated. The oyxgen of the air at once attacks the iron and changes it to the insoluble form, leaving the iron hanging from the roofs of caves in the form of stalactites or falling to the floor builds up stalagmites. This process may continue until the entire cave is filled with "pipes" of iron ore in the form of limonite.

Iron in solution carried by water.

Growth of Large Deposits. Instead of this, or in connection with it, let us imagine a moderately large stream entering a cave. The upper surface of the water is exposed to the air. The iron, as before, becomes oxidized, but in this case being heavier than the water it sinks to the bottom.[1] If the supply be sufficient, the cave will be filled with the precipitated limonite and thus a "pocket" or deposit of iron will be formed. The water which

Ore deposited in cavities.

[1] In the summary of the final report of the Geological Survey of Pennsylvania, 1892, p. 425, Prof. J. P. Lesley, in a chapter on "Caverns and Sink Holes in II," describes, in a very clear and concise manner, phenomena which I have attempted to point out in the Ozarks. In the same chapter he gives numerous examples of the rapidity with which limonite accumulates in caves and in artificial openings.

carries the iron in solution will be very likely also to carry in, mechanically, much clay and fine sand which will, in the quiet water, settle, together with the precipitated iron, thus forming the lenses of clay and sand so often found in the iron banks. Further, the limestone forming the roof of the cave may contain layers of chert. This, as the limestone is etched away, will eventually fall and thus give rise to the layers of chert in the iron ore. It may further be imagined that the cave itself may have more than one floor owing to layers of impure, and thus less readily soluble limestone. These layers or floors may in time be entirely enclosed in the precipitated iron, thus adding very essentially to the amount of foreign matter in the ore. This process may continue until the entire limestone bed above the cave is etched away leaving the cave partly or wholly filled with iron, covered with a mantle of residuary clay and chert.

imonites are e impure.

Process of Concentration. Let us see what this process thus briefly outlined may result in, under the most favorable circumstances. In all bedded rocks, sandstones especially, there is more or less of iron present, either as a cementing material in ferruginous sandstones, and, in limestones, in the form of sulphide and also as limonite. This iron is so slight in quality and so evenly disseminated as to be utterly worthless as an ore of iron. On the surface of these rocks, covered with soil, there will be vegetation more or less dense. This surface vegetation decays. Water falling in the form of rain or snow carries it into the underlying rock and brings it into contact with the contained iron. Little by little, under the reducing action of water charged with organic matter, the hard ferruginous sandstone looses its cementing iron by solution and becomes more and more friable, until all but the last traces of the iron cement disappears.

ation and entration.

In a country whose broken and faulted rocks are thrown up in the form of hills and mountains, these iron bearing waters may find their way over the surface in the form of surface brooks and streams. But, in a limestone country, with low dipping rocks elevated over a large area, the case is very different. The underlying limestone would be slowly but surely attacked. The rainfall would find its way through joints in the

of broken s.

limestones and along seams between its beds, which would continually be enlarged. Gradually there would be formed caves of varying dimensions. In the beginning these would be most apt to be found near the highest points of the country.

Topographic Relations of Deposits. As time goes on these underground waters would join in larger underground streams until the overlying rocks would be undermined and a narrow, gorge-like valley would be the result. Caves in the limestone have also been formed at these lower levels, and the iron bearing waters begin newer and, of course, larger deposits. The deposits would be larger from the fact that the larger the water shed or drainage area and the deeper the valley the greater would be the flow of ferrugineous waters at any one point in this area. The waters could also draw from a greater volume of ferrugineous rock. It can further be imagined that the smaller deposits, first formed high up on the sides of these valley or near to the sources of the streams which cut them, would, in many cases, be exposed to the action of waters carrying organic matter, and thus these deposits would be dissolved and re-precipitated at successively lower levels.

Movement of deposits.

In the winding valleys of these streams the waters impinge, first on one bank, and then on the other. The bank against which the stream impinges will have its rocks swept bare of all clay and soil. Not only this but the rocks will be undermined and fall from time to time leaving in places almost or quite perpendicular bluffs. From the sides and from the foot of these bluffs often issue springs fed by the waters falling on the hill above. These waters will doubtless be ferruginous but, passing directly into the stream itself, the iron which they carry will be swept away. On the opposite side of the stream the steep bluffs are replaced by easily sloping hills with hardly a trace of bedded rock. These sloping hills are composed of thick beds of gritty clay mingled with fragments and layers of chert, the remnants of former beds of limestone. These beds of clay show clearly that the soluble limestone has been slowly etched away, leaving the insoluble matter in a stratified form, and that hence, during this slow etching process any ferruginous waters would have time for the iron in the water to become oxidized and thus precipitated.

Concentration by removal of limestone by solution.

A cavern started in the beginning would slowly enlarge and would be wholly or partially filled with limonite either in the form of pipes or in solid layers or both. Whether the flow of ferruginous waters ceased with the removal of the limestone or not, the end would be an iron deposit imbedded in stratified clays and chert. To review briefly the points in this indirect process we have the following steps:—

Steps in the development of limonite banks.

First the iron, in whatever form it may have been at first, becomes hydrated.

Second. By organic matter it is rendered soluble.

Third. This soluble iron is carried to some lower level.

Fourth. It is re-oxidized and precipitated.

It becomes very evident then, that, when this process first begins, deposits will form high up in the drainage area, but, as the underground waters cut deeper and deeper into the limestones, deposition will gradually cease at these higher levels to be carried on lower down. As a consequence one can imagine that, high up on steep rocky hills may be exposed deposits of iron shut in by limestone rocks. Lower down, when deposition has taken place, the deposits may be wholly or partly covered by clay which has been left from the solution of the limestone; and, in addition, that which has been washed from the hills above. Thus a very unpromising outcrop located on low clayey hills may develop into large and valuable deposits.

Facts bear out above theories.

The above explanation is well borne out by facts. Along the crests of the great divides between streams like the Current and Black rivers there are numerous localities where large blocks of remarkably pure limonite are found. These blocks are often casts of small cavities in the limestone and were, formerly, many of them, sulphide of iron. Mingled with these fragments of iron ore are blocks of weathered limestone, and the main body of this limestone is weathered into ridges which stick up through the shallow soil. Many of these places have been dug into, but solid limestone has invariably been struck at a few feet. Localities, on the other hand, which have been prospected at the foot of easily sloping hills with no outcropping rocks have turned out differently. The Lamons bank at West Plains, Mo., is a striking case in point. Mount Nebo, near Alton, in Oregon

county, illustrates both cases very well.[1] In this place iron shows in great profusion at the summit but limestone is found only a few feet below the surface. At the foot of the hill where no rocks showed, a shaft sunk to a considerable depth penetrated about eighteen feet of ore. Other localities near West Plains have had shafts sunk upon them, where the hills were without solid rock, and, while none have shown up as well as at the Lamons bank, they go far to establish the reliability of the above theories. The Lamons bank.

The Processes of Deposition. In the few preceding pages the process has been briefly outlined by means of which an iron ore deposit may be gradually removed, either by leaching and collection of widely disseminated iron or by the slow removal of a large deposit. The method by which the iron is put in solution is generally a uniform one, *i. e.*, by means of organic acids, but the method of deposition as limonite, as we find the ore bodies now, is neither simple as to the method nor is it done by a single process. There are almost numberless explanations given based on correct chemical reasoning, of how such deposition may take place. But, when applied to the great number of deposits observed, no one explanation will suffice and it is by no means probable that even any one deposit may be explained on one theory of deposition alone. It is more than likely that a half dozen or more causes have combined to produce a given deposit. In treating of the limonites of the Ozark Uplift, therefore, no single theory is adopted; only the general principles are pointed out. Iron in solution as a sulphide, coming in contact with lime or magnesium carbonate, will be precipitated either in the form of pyrite or marcasite, or, in the form of protoxide and it may be directly oxidized to the hydrous peroxide state, that is, limonite. In the form of a sulphate, sulphide or carbonate it is unstable, and in the presence of certain reagents it will assume the hydrated form. That all of these forms have existed there seems to be abundant proof. Limonite pseudomorph after pyrite and marcasite are often found. Traces of carbonate enclosed in masses of limonite

Chemical process of deposition complex.

Iron tends to assume the hydrated form.

[1] See illustrations of these deposits in this chapter, pp. 164–171.

seem to testify to the change from a former carbonate. The sulphates, being readily soluble, would probably change to a carbonate at once on contact with either calcium or magnesium carbonates, and are hence not found.

Migration of Iron Deposits. Finally, the effect of topography, not on iron alone but on all mineral deposits, is to cause such deposits to be continually moving from a higher to a lower drainage level. In a great plateau region, which we may consider the head of mineral streams as well as of the drainage waters, we must look constantly for a movement from above downward, and the rapidity of the movement will be dependent upon the area and amount of water. No more would we look for large bodies in the narrow gorges and rocky hills of the flanks of the Ozarks than we would look for lakes and ponds and quiet streams. Here all is motion and activity. But when easier slopes have been reached, when narrow gorges have widened out into rich river bottoms, and the contours of rugged and rocky hills have been softened into easy slopes, here are quiet waters and here is where deposition and accumulation begins on a large scale. In view of the facts thus set forth it seems to be not at all a hazardous prediction to say that in the great drainage systems of the Ozark Uplift will be found the key to the great mineral deposits, not of iron alone, but of lead and zinc of Southern Missouri.

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THE VALUE OF THE MISSOURI LIMONITES.

In calling to mind the facts recorded in regard to the Missouri limonites there are two which stand out very prominently. First, that the Osage river district has been known for more than twenty years and that one attempt has been made to work the ores of this district by means of a local furnace and this one has failed. Second, that the limonite field of the southeastern part of the State has been worked, that a good many thousand tons of ore have been shipped, but that all of this was nearly twenty years ago, and to-day absolutely nothing is being done in spite of the fact that hundreds of untouched deposits are easily accessible by rail.

...iron works ...ed.

The question naturally arises, if these iron ores are of value, as

chemical analyses seem to show, why are they not worked. Limonite is the lowest class of iron ore but one. This will be seen by referring to the table of iron ores on p. 3 of this report. Add to this fact the natural impurities of limonite and it gives an ore that is valuable only under certain circumstances. Whether these conditions are under control in such a way as to make these deposits valuable, will be pointed out in the following pages. Limonites a low class ore.

Whatever work has been done on the iron ores of the southern part of the State has strengthened the disfavor in which they have been held from the first. The iron masters of St. Louis, which point is the only available market at present, regard these ores as too highly siliceous and phosphatic to be available. In addition, they believe the deposits to be in small pockets, to be scattered and though exposed at the surface, to be so thoroughly mixed with dirt and rocks as to cost more for digging than do lower grade ores which have to be mined. They are regarded with disfavor.

Chemical analysis seems to warrant this conclusion. Referring to the analyses on pp. 170 to 178, we find that the yield of iron is low while silica is high. We see that the ores which were shipped from southeastern Missouri are of lower grade than those taken from the Ozark district proper. Mine samples from Stoddard, Wayne and Butler counties give: —

	1	2	3	4	5	6	7	8	9
Silica and insoluble	7.46	33 97	14.72	15.29	17.19	42.25	10.46	25.97	25.98
Metallic iron........	55.70	37.36	52.06	52.41	49.30	35.01	52.30	44.93	44.27

Analyses of limonites from the Miss. district.

The average of silica and insoluble matter is 22.13 per cent.; metallic iron, 47.04 per cent. These ores are high in phosphorus, or at least too high for Bessemer pig.

Comparison with Foreign Limonites. From "The Report of Progress in the Laboratory of the Survey:" "Second Geological Survey of Penn., 1874 and 1875:" nine analyses of the limonites are selected for comparison with the Missouri limonites. The analyses are of ores worked and smelted in Pennsylvania furnace and are as follows: —

	1	2	3	4	5	6	7	8	9
Silica and insoluble	28.99	39.05	16.23	21.06	16.30	34.25	10.05	11.89	20.21
Metallic iron........	37.00	32.70	46.60	45 30	46.50	33.30	47.00	47.90	45.70

Analyses of limonites from Penn.

The average of the silica and insoluble constituents in these ores is 22.00 per cent, while the yield of metallic iron is only 42.44 per cent. as against the 47 per cent. of the Missouri ores.

Lehigh, Penn., limonites.

Quoting the introduction to the analyses of the brown ores from the above mentioned work (p. 48): "The number of brown hematites ores examined from Lehigh county, Pennsylvania, is thirty-eight. The percentage of iron found varies from 28.10 to 58.50 per cent. The mean average per cent. 46.09. The amount of sulphur present is invariably very small; the average per cent. being only 0.025. The per cent. of phosphorus varies from 3.135 to 0.025. The mean average per cent. of the thirty-eight samples examined is 0.344. The insoluble residue gives, as the average, 17.16 per cent."

Compared with Howell Co. limonites.

It is not quite fair to the Missouri limonites to compare them with the thirty-eight analyses from Pennsylvania, but even doing this the result is that the siliceous Missouri ores yield one per cent. more of iron than do the others, although they are higher in insoluble matter by five per cent. This, however, is from the acknowledged most siliceous ores. The high grade of limonite already mentioned as being taken from the Lamon's bank near West Plains, is really more nearly typical of the main bulk of the Missouri limonites. This bank has been so thoroughly sampled that no hesitation is felt in taking this as a true standard by which to judge of these deposits. Analyses of this ore kindly furnished by the company are as follows:—

Analyses Lamon's bank.

	1	2	3	4	5
Water	10.97	11.07	11.25	11.37	10.08
Silica	7.63	6.02	2.70	4.11	3.08
Iron	56.96	56.40	59.90	57.94	59.36
Sulphur	0.05	0.049	0.037	0.063	0.72
Phosphorus	0.104	0.115	0.087	0.118	0.57

Mr. Birkenbine quoted.

For further purposes of comparison we will now quote the average yield of metallic iron per ton of ore from other iron producing States. For this purpose the report of the Eleventh Census of the United States will be freely drawn upon. In the "Census Bulletin No. 113, Mines and Mining, Iron Ores," Mr. John Birkinbine, M. E., collects the following data:—

The returns from the blast furnaces of Alabama, the leading iron producing State in the Union, represent 90 per cent. of its

total output. They also show that the majority of the ores used were from local mines, with the exception of a small amount brought in from Georgia. The average yield per ton was 46 per cent. metallic iron. Seventy per cent. of the ore used was red hematite; the balance was brown hematite or limonite.

Iron in Alabama.

The blast furnace reports show that in the range of ores used, metallic iron varied from 30.5 per cent. to 51.6 per cent. with the average, above stated, of 46 per cent. The three New England States which smelt iron are Maine, Connecticut and Massachusetts. Full reports show that they use local ores entirely; that brown hematites are the only ores mined and that the average yield is only 44 per cent. metallic iron. Colorado uses 55 per cent. local ores. The ores used in the Georgia and North Carolina furnaces are local, of which 75 per cent. is red hematite and the remainder is brown hematite with a yield of 44.7 per cent.

New England product.

Illinois mined no ores of any kind. Her supply was obtained entirely from the Lake Superior region. Of this 94 per cent. was red hematite, two and one-half per cent. magnetite, and the remainder mill cinder. The average yield of metallic iron was 60 per cent.

Illinois.

Kentucky used local ores entirely, chiefly carbonates and brown hematites, and these yielded in the furnace 46.2 per cent. of iron.

Kentucky.

Maryland has two classes of furnaces, those using exclusively local and Virginia ores and those using imported ores. The furnaces using local and Virginia ores exclusively yield only 41 per cent. of metallic iron.

Maryland.

The majority of Michigan furnaces are located within easy distance of the mines and depend upon charcoal as a fuel. They use an ore which cannot stand transportation and which yields only 58 per cent. as against 60 per cent. in Illinois and 61 per cent. in Pennsylvania. Red hematites form the bulk of their burden, though magnetite and brown hematite is used to some extent.

Michigan.

Missouri blast furnaces use local, specular ore (equal to red hematite) with a small admixture of brown hematite.[1] The furnace yield is 56.4 per cent.

Missouri.

[1] I know of no brown hematite or limonite iron ores mined in Missouri at present. So far as I have learned none have been mined and shipped since

The blast furnaces of New Jersey depend chiefly upon local magnetite mines, but draw some of their charges from the Lake Superior region. Some ore is brought from New York and a very small amount from Pennsylvania. These ores, mixed with rsey. some foreign ores, bring the yield up to 51.9 per cent. Even when New Jersey ships her magnetite ores, many of which are shipped, they go to furnaces in the Lehigh valley and other places in Pennsylvania, none of them more than a hundred miles from the mines, though some of the mines yield ores which are shipped on a guarantee of 65 per cent.

The New York ores are about one-half magnetite, the balance rk. red hematite with some brown hematite and carbonate. The average furnace yield is 47.6 per cent.

Ohio obtains the bulk of her ores from the Lake Superior region and from local carbonates; magnetite from New York and red hematite from Missouri are also used. The result of the mixture of low grade home carbonate ores and imported high grade ores from neighboring States is an ore which yields 55.7 per cent. of iron.

Oregon uses a brown hematite exclusively and gains only 32 per cent. of iron.

Pennsylvania is by far the most interesting State. It stands next to Alabama. But while Alabama uses almost wholly local vania. ores, eighty-five per cent. of what Pennsylvania uses are imported ores. Alabama's furnaces' yield is 46 per cent.; while the average for Pennsylvania is nearly ten per cent. greater, being 55.3 per cent. Some brown hematites are shipped from Virginia, but by far the greater part of the brown hematite used comes from

1886, with the exception of a few thousand tons mined in Howell county. But this brown hematite was used as lead flux and not as an iron ore. In the specular ore mines Simmons mountain, Plank mine, Hawkins mine and Cherry Valley, and especially from Simmons mountain, there is however, a considerable percentage of brown hematite which has been derived from the specular iron ore by weathering. At Simmons Mountain this is sorted out and shipped as limonite or brown hematite. Brown hematite is especially likely to occur when opening a new bed of specular ore, along seams or in the extension of old mines. It also occurs surrounding blocks or masses of solid specular ore. These facts will probably account for the statement as to the admixture of brown hematite in the Missouri ores. F. L. N.

local mines. Local carbonates are also used as well as carbonates from Ohio. It is especially interesting to note the character of the imported ores. Hematites from Spain and Africa yield of metallic iron 63.6 per cent. and 60.2 per cent.; lake Superior ores, 61.5, 61.8, 62.6, 60.8, 60. and 59.5 per cent.; Pennsylvania magnetites yield 51., 50.9, 49.1, 48.9, 48.5 per cent.; Pennsylvania brown hematites yield 41.5, 45.6, 41.2: local fossil ores, 37.9 and 36.9 per cent. Ores from Cuba and Mediterranean ports yield 56.6 per cent. of metallic iron. The entire blast furnace yield for the State is 55.3 per cent. Pennsylvania continued.

The chief source of supply of the Tennessee furnaces are the brown hematites, locally mined and brought in from the neighboring States, Alabama and Georgia; carbonate ores are also used. Furnace yield for the entire State is 39.6 per cent.; for furnaces using brown hematite alone, 38.8 per cent. Tennessee.

Texas uses brown hematites exclusively, which are mined in the State. When roasted they yield 45.8 per cent. Texas.

Virginia depends almost entirely upon her brown hematite mines, which supply eighty-five per cent. of the ores used, the balance comes from local red hematite mines and from magnetite mines in North Carolina. The ores from these sources yield 43.4 per cent. of iron. Several furnaces depending entirely upon brown hematite show percentages of 48.6, 43.3 and 41.4 per cent. of iron. Virginia.

In Washington local brown hematites are mixed with magnetites imported from British Columbia. The resulting furnace yield is 64 per cent. Washington.

West Virginia brings the bulk of her ores from the Lake Superior region. These are sparingly mixed with local brown hematite, carbonate and a small amount of magnetite. The result is a furnace yield of 60 per cent. of iron. West Virginia

Wisconsin's blast furnaces use Lake Superior ores. These, red and brown hematites, were the only ores used and gave a furnace yield of 57.2 per cent. of iron. Wisconsin.

Conclusions from this Comparison. Even a casual glance at the above statements, taken from the Census Report on Iron, brings out two facts in bold relief. First, only high grade iron ores are shipped to any great distance; and second ·de

ores, if used at all, must be used at producing points. A third fact also stands out very prominently: *i. e.*, that a State remote from an iron center, but which consumes a considerable amount of iron, finds it profitable to work a very low grade ore. Ohio, Pennsylvania and Illinois are three great iron-producing States. Illinois mines no ore, but brings very rich ores from the outside; Pennsylvania and Ohio each mine less ores than they consume, and the ores which they produce are lean. The ores which they buy outside are high grade. Alabama, Texas, Tennessee and other States where lean ores are abundant, smelt them on the spot where they are mined. The pig iron is either locally consumed or shipped to central markets. A ton of pig iron which is made from a sixty per cent. ore, or one which is made from a thirty per cent. ore, is equally valuable, and can be shipped side by side for an equal distance and can compete on equal terms. But the case is entirely different when we consider ores. A sixty per cent. ore pays freight on only forty per cent. of impurities, whereas a thirty per cent. ore pays freight on seventy per cent., nearly twice as much. The higher grade ore can thus drive the other out of the market. If we regard as demonstrated the fact that lean ores can not be shipped to great distances, the question arises, — What are the conditions which make this local smelting of lean ores possible?

ce yields pared.

Conditions Necessary for the Successful Manufacture of Iron. Perhaps the best possible answer to a question of this nature is to point out the conditions favorable to iron smelting, without which success is not attainable. These conditions briefly summed up are as follows:—

1. An abundance of cheaply accessible ore.
2. An abundance of fuel close at hand.
3. Water.
4. Pure limestone.
5. Competing transportation lines.
6. Markets.

conditions.

The Quantity of Ore Available. — As to the abundance of iron ores, this question has been amply discussed under the general headings of the iron ore districts into which Missouri has been divided. The map accompanying this report shows the

great number of the deposits, while the dimensions of the Lamon's bank, p. 169, will give some basis for an estimate of the yield for each bank.[1]

While an attempt has been made to make this map showing the location of iron banks, as complete as possible, many locations with surfaces exposed must necessarily have been overlooked, to say nothing of banks which doubtless exist, but show few indications on the surface. It is true that many of these banks may be, and probably are, of very limited extent, yet it is also probable that many will exceed their promises by yielding a large amount of ore. The conclusion is reasonably certain that the first of the conditions enumerated is exceptionally well satisfied. **Map of Missouri ore districts.**

The Quality of the Ores. As to quality, the analyses quoted as being made by previous surveys, as well as by the present survey, show that even the more siliceous ores rank in percentage of iron above the limonite ores mined and smelted in Pennsylvania, and rather better than the red hematite ores of Alabama. Analyses also show that there is a reasonable ground for hope that mining operations will show deposits sufficiently free from phosphorus to enable them to be used for Bessemer purposes. The fact that these ores are exclusively limonite will necessitate their being roasted to free them from (a) hygroscopic water, and (b) combined water. **Grade of Missouri limonites.**

The Transportation Facilities. The accompanying map also shows that a great part of these ores are very accessible to lines of railroad which are already in existence. In the Mississippi district the Iron Mountain road with its spurs makes accessible the ores in Iron, Reynolds, Wayne, the eastern part of Carter and the whole of Butler, counties. The Belmont branch of the same road passes through St. Francois, Madison and Bollinger counties. The St. Louis, Cape Girardeau and Fort Smith railway opens up the extensive iron belt of Stoddard and Wayne counties. This line is at present completed to Hunter, in Carter county, where it connects with the Current River road. The **Shipping facilities for limonites.**

[1] This map by no means shows all of the deposits of brown hematite and specular ore. In the great limonite and hematite ore fields coverin
of square miles only the most readily accessible points have been n

extension of the "Houck road," as the Cape Girardeau road is called, to Fort Smith, will make still more accessible an extensive belt of iron ore in Carter, Oregon, Howell and Ozark counties. The line of this extension has already been surveyed and it is only a matter of a few years before it may be constructed. The Current River road also passes through an extensive belt of iron ores in Carter, Shannon and Howell counties; while the Kansas City, Fort Scott and Memphis makes accessible deposits in Wright, Douglas, Texas and Howell counties. The last roads, as well as the proposed extension of the Houck road, will very effectively open up the greater part of the Ozark district. The extension of the Salem and Little Rock road will also render more accessible the deposits of iron in parts of Dent, Shannon, Texas, Douglas, Howell and Ozark counties.

Shipping facilities.

In none of these counties can transportation by water be depended upon. The Black, White and Current rivers are so swift as to be practically unnavigable in Missouri, although, on account of their size, they otherwise might be made serviceable. For a check then upon exorbitant freight charges, dependence must be placed entirely upon competing lines.

Water unreliable.

It may be suggested that a line of railway can at best only open up a country, so far as iron ores are concerned, for a distance not greater than three miles on either side of a road, and this is only a comparatively narrow belt in the great area of southern Missouri. The answer to this objection is comparatively simple. The main lines of road run parallel, or approximately so, to the great drainage streams of the southeastern slope or cut across them in such a manner as to make their valleys readily accessible. Into these great drainage valleys, narrow as they are at times, open innumerable minor gorges or valleys; these, while often narrow and rocky, present road-beds for spurs to any deposits of iron which may lie in them. Grading for a road-bed would be comparatively simple, and the cost would be reduced to a minimum on account of the timber which would be found growing besides any proposed route. When a given deposit was exhausted, rails and timber could be easily removed elsewhere. This system of building spur roads is already extensively made

Divides favorable to railroads.

use of by lumber companies in opening up new timber belts remote from their mills.

In the Osage river district the problem assumes a practically different phase. Although there are three roads running *towards* this area only two reach it. Even these two only reach the northern border and are practically of little or no value in developing the district, as they are now. If, however, any one of the three be extended, as there is talk of doing, a long step will be taken in making these deposits accessible by rail. At present, however, the main dependence, bad as it is, must be placed upon the Osage river. As has been mentioned before, the Osage river district is narrow and closely flanks the river whence it takes its name. In high water, or even moderately high water, a part of the Osage could be made available for floating its ores to a point where a furnace might be erected. By mining out large bodies of ore and storing them at the river bank, advantage could be taken of a rise in water to float down a sufficient stock to last over a period of low water. The same policy could be pursued in the shipment of its pig iron to the Missouri river or to the Missouri Pacific railway. In this manner the river, though not so reliable as a railroad, could be made an effective check against exorbitant freight charges.

Osage district dependent on rivers.

A furnace plant located near Williamsville would have a position favorable for fuel, ores, water and, although there would be no water transportation for iron, two competing lines of road, the St. Louis, Cape Girardeau and Fort Smith and the St. Louis, Iron Mountain and Southern would be within easy reach. Thayer, in Howell county, is another point which would possess all the advantages of the above named place, save competing lines of road. But in the event of the extension of the proposed lines this objection would disappear.

Location of furnaces.

The Fuel Supply. Another imperative factor in the establishing of local furnaces is an abundant supply of a good fuel. In spite of the sanguine but baseless hopes of many, there are no true coal fields in southern Missouri. There are numerous limited areas of coal shales, and, in places, bits of coal and coal fossils are found, but these are in ravines bounded on either

side by rocks of the Ozark series, which surely limit their extent to a very small area. There may even be found pockets containing coal similar to the one on Sligo brook in Crawford county, and also near Versailles, in Morgan county, and which contain many hundreds of tons of fairly good coal. But even if such pockets should be found, which is extremely doubtful, they would not at all alter the statement that there are no great coal fields in this part of the State. For fuel for any furnaces which may be erected recourse must be had to other sources of supply, for it is impracticable to bring either coal or coke to this region for this purpose.

fields in
arks.

Timber for Charcoal. The fact that the greater part of this region is covered by forests, although they are light in many places, presents a ready solution to the question. The country which is covered by forests must be divided into two very important sections: upland and bottom. The chert hills, or upland, even when the hills are thickly covered with chert, are more or less heavily timbered. The growth is, with few exceptions, that which is best fitted for charcoal: black oak, jack oak, white oak and post oak are the principal varieties of oak; while there is also a fair amount of black and white hickory. The growth is rarely large, and an estimate of a man of wide experience in charcoal furnaces, Hon. David Carson, of West Plains, puts, as a conservative estimate, an average yield of fifteen cords to the acre. There are many extensive tracts where this could be easily multiplied by ten and still be within conservative limits. For charcoal purposes, oak and hickory are excelled only by beach, maple and birch, which woods supply the charcoal for the Wisconsin and Michigan furnaces.

l timber
lant.

In the bottoms a very different set of conditions prevail both as to quantity and quality of the growth. The oaks are represented by the black, white, burr, water, chinkopin and spotted varieties. Hickory is also fairly abundant. But the most abundant trees are the sweet and black gums, cottonwood and sycamore. The hackberry is also rather abundant. [illegible] As to the number of cords per acre which these bottoms would yield it is hard to say, but oaks with a diameter of from three to five feet are not uncommon, while the

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sycamore is often over five feet. In other words, it is not uncommon that a sycamore tree is large enough to make six cords of wood, or more. Bearing in mind that these river bottoms are extremely fertile it will be easy to imagine a dense forest that is capable of yielding hundreds of cords to an acre instead of the fifteen (average) of the upland.

There is, of course, a decided difference in the value of charcoals produced from different woods. This value depends upon a variety of qualities. One of the first, is economy in weight. Haswell[1] gives the following values for different woods, taking the weight of the wood dried at 300° F. as 100 per cent.: —

Comparative value of woods for charcoal.

Oak	yields	46.09	per	cent.	of	its	weight	in	charcoal.
Beech	"	44.25	"	"	"	"	"	"	"
Elm	"	34.59	"	"	"	"	"	"	"
Birch	"	34.17	"	"	"	"	"	"	"
Maple	"	33.75	"	"	"	"	"	"	"
Ash	"	33.28	"	"	"	"	"	"	"
Poplar	"	31.12	"	"	"	"	"	"	"
Pine	"	41.48	"	"	"	"	"	"	"

It will thus be seen that oak ranks very high. Hickory, sycamore and gum are not given, but hickory will rank with oak, and sycamore and gum, as well as cottonwood, will rank with poplar and elm.

An important property to look for in a charcoal for smelting works is hardness. In a blast furnace of even moderate height the weight of the charge of limestone and iron must be borne by the fuel employed. If this fuel is soft, like bituminous coal or charcoal from poplar and other soft woods, the fuel crushes and forms a mat or blanket, which is almost impervious to the blast. Consequently a charcoal must be hard in order to resist this crushing effect. In the absence of more exact data, the opinion of a charcoal furnace man is given in regard to the relative strengths of different charcoals. By him beech and maple are put first, while oak and hickory follow close behind. Sycamore, gum, elm, and poplar rank low. In actual practice, though, at the old Meramec furnace, all timber was used, upland and bottom, irrespective of kind. The softer woods

Hardness of fuel necessary.

[1] Mechanics and Engineers Pocket Book, p. 481.

were charred in separate kilns, and they, especially the sycamores, were allowed to become thoroughly seasoned before charring. In charging the furnace 25 per cent. of sycamore and other soft wood charcoal were used with no further ill results than a slight increase in the cost of the fuel. This increase is due to the fact that it takes more of the softer coal to make a ton of pig iron than of the harder.

ures of
ods.

The above mixture comes almost naturally in the growths of the river bottoms. But if it were desirable to reduce the per cent. of soft coal charged an increase in the upland wood could easily be made in the kilns. This is rendered possible by the fact that the softer woods are found almost exclusively in the bottoms, though mixed with a good proportion of hard wood; while the upland has no soft wood save in the pine belts.

abling woods
coal.

The facilities for assembling these woods to central points where they could be charred and used in a furnace are equal to the facilities for collecting the iron ores, and even better, for small streams during high water could be made to float wood to a railway where it could be caught in booms and loaded on to cars. All the railways before referred to run through timbered sections and, as they use the mineral coals so abundant in the State in other sections, they would have no influence in diminishing the charcoal supply. Moreover, owing to the nature of the country, the greater part of the forests will remain as forests for years. The cherty hills are so thickly strewn with flint that agriculture is well-nigh impossible, though in the future they will, no doubt, be available for fruit.

elts thickly
bered.

All ore belts are covered as thickly with timber as are any other sections of the country, and thus spurs, run from a main trunk to an ore deposit, could be utilized if necessary in the collection of fuel.

Value of Lands. It may not be out of place to note in this connection the value of arable land in this section of Missouri. The richest lands are the river bottoms and these are the most heavily timbered. The cost of clearing these bottoms is estimated at $25 per acre. This cost makes the land almost wholly out of the reach of the ordinary settler. The timber growing on the land must be cut off and burned at a great expense and

nothing is recovered, as there is no market except for the best oak and hickory. Thus there are many extensive land-owners of these river bottoms who would gladly give the timber to any one who would clear the land entirely. It is thus evident that the establishing of an iron industry would be of great and permanent benefit in clearing these rich lands and making them available for agricultural purposes. With this statement of facts it can be readily seen that the fuel question is practically settled for a good many years at least. It is further true that the fuel is of the very best, for charcoal iron, if properly treated in the blast furnace, is one of the most valuable of irons. Two medium sized furnaces using charcoal exclusively, have already put this fuel question to a practical and profitable test. These two furnaces, the Sligo and Midland, in Crawford county, have been running for many years. The Meramec furnace, near St. James, went out of blast on account of difficulty of transportation and not from lack of fuel or ore.

Arability of river bottoms.

Limestone Available. Another important factor in iron smelting is limestone. This is, however, so abundant that it is almost superfluous to mention the fact. Even in the sandstone regions of the specular ores it is readily and cheaply obtained. It is, almost without exception, magaesian, but on this very account it is well fitted for blast furnace use. The appended analyses show the composition of several samples of this rock. They are in places cherty and in others highly siliceous, and in still others high in alumina in the form of clay. But even in regions where such exist others can be found remarkably pure.

Magnesian limestone.

ANALYSIS OF MAGNESIAN LIMESTONE FROM IRON COUNTY, MISSOURI.

Copied from the Report of the Geological Survey of Missouri, 1872, Part I, p. 38.

Analysis of magnesian limestone.

	A.	B.	C.	Pyritiferous
Insoluble and siliceous	5.11	3.85	2.06	17.88
Peroxide of iron and alumina	4.67	1.07	none	3.75
Carbonate of lime	47.50	52.50	54.32	43.25
Carbonate of magnesia	42.19	42.56	43.82	34.25

The Water Supply. It seems on first thought to be a little strange that, with the abundant rainfall of the Ozark mountains,

some places, otherwise desirable for the location of a blast furnace, might be rendered totally unavailable on account of an insufficient and an unreliable water supply. Such is nevertheless the fact. Nothing at first sight is more surprising to the traveler than that he can oftentimes go for miles without finding a single stream. Torrential flows there are at intervals in abundance, but these entirely disappear in a few hours after a heavy rain. Even wells would fail to obtain a permanent supply of a large volume, though they are able to satisfy all ordinary requirements; the cisterns to catch the rain often resorted to, are not from necessity, but from preference in domestic use. The tough clays which usually overlie the limestones are easily formed into reservoirs sufficient in size to furnish generally an abundant supply for cattle and stock.

Water carried off underground.

But with blast furnaces the case is different. A very large supply of never failing water must be had in order to successfully operate and, had dependence to be placed entirely upon surface flows, their operation would be, in many localities, impossible. But the very cause of this lack of surface water is the fact that the country is of limestone and the water thus finds its level by means of underground channels. This fact is abundantly testified to by the numerous springs of extraordinary size which are found in this part of the State.

Furnaces need surface water in abundance.

It will thus be readily understood how there are many places in the Ozarks where an abundant supply of never failing water may be had. The springs above referred to are numerous and of large size, and when once they come to the surface they rarely or never again go underground. They are then surface streams. In regard to a water supply for furnaces, it may be said, then, that localities can be selected, in other respects auspicious, where water is abundant.

Springs of large size.

Markets for Iron. There is very little doubt but that iron could be manufactured in the Osage river belt, shipped to St. Louis and there compete on favorable terms with iron from Tennessee and Alabama as well as from Illinois and Wisconsin. But the most hopeful location for future markets is to the west and southwest. In the great stretch of territory from the Mississippi to the Rocky mountains, including Nebraska, Kansas,

Indian Territory and Arkansas, a great agricultural country, there are few, if any, iron ores. There must be a great consumption of iron in agricultural implements, structural iron and all the varied uses to which iron is put. As it is now, iron ores are mined west and south, shipped east, smelted and manufactured and shipped back west. Thus, to say the very least, the subject of home smelting the limonite ores of Missouri and of manufacturing them into articles of commerce is a point well worth considering.

Southwest a growing consumer of iron.

Cost of Producing Pig. For reasons before enumerated, cheap labor, cheap fuel, cheap iron ores, the initial cost of pig iron ought to be very low. To bear out this statement we append an estimate made by Hon. David Carson of West Plains, Mo. Mr. Carson has been engaged for twenty years in making charcoal pig iron in this State, and, as will be seen, his estimate of cost throws strong confirmatory light on its probable ability to compete with other irons. The calculations are based on minimum, maximum and average costs.

Estimated cost of pig iron.

COST OF EACH CORD OF WOOD AT FURNACE.

Wood.

	Min.	Max.
First cost of wood per cord	$ .40	$ .50
Royalty	.10	.10
Loading from banks to railway	.15	.15
Hauling to railway	.40	.40
Freight to furnace	.45	.45
Wood receiver	.05	.05
	$1.55	$1.65

Average cost per cord at furnace, $1.60.

COST OF ONE HUNDRED BUSHELS OF CHARCOAL AT FURNACE.[1]

Charcoal.

	Min.	Max.
Cost of two cords of wood	$3.10	$3.30
Expense of charring	.65	.75
Repairs	.50	.50
	$4.25	$4.55

Average cost one hundred bushels at furnace, $4.40.

[1] Each cord of wood yields fifty bushels of charcoal.

ores.

COST PER TON OF IRON ORE AT FURNACE.

	Min.	Max.
Mining per ton	$ .50	$1.00
Royalty	.10	.10
Unloading	.05	.05
Freight by rail	.30	.30
Roasting	.12	.18
	$1.07	$1.63

Average cost per ton at furnace, $1.35.

stone.

COST OF LIMESTONE PER TON OF PIG IRON.[1]

	Min.	Max.
Mining per ton	$ .25	$ .35
Freight by rail	.30	.30
Royalty	.05	.05
Unloading and crushing	.15	.30
	.75	$1.00

Average cost per ton of limestone at furnace, $.80.
Average cost per ton of pig iron, $.40.

e.

COST OF LABOR PER TON OF PIG IRON.[2]

		Min.		Max.
1 founder		$3.00		$3.50
1 night foreman		2.00		2.50
1 first engineer		2.50		3.00
1 second engineer		1.25		1.50
2 keepers	at $1.50	3.00	at $1.65	3.30
4 helpers	at 1.25	5.00	at $1.40	5.60
2 topfillers	at 1.35	2.70	at $1.50	3.00
4 bottom fillers	at 1.25	5.00	at $1.40	5.60
4 coal forkers	at 1.25	5.00	at $1.40	5.60
4 crusher men	at 1.00	4.00	at $1.25	5.00
3 cinder men	at 1.25	3.75	at $1.50	4.50
8 iron carriers	at 1.25	10.00	at $1.50	12.00
2 cart boys	at .60	1.20	at .75	1.50
1 watchman		1.25		1.50
6 laborers	at 1.00	6.00	at $1.25	7.50
1 weigh clerk		1.50		2.00
1 carpenter		2.00	at $2.60	2.50
4 cart mules	at .75	3.00	at .75	3.00
		$[illegible]		$73.10

[1] Based on one hundred tons of iron ore per day, charging with 20 per cent. of limestone or 2[illegible] tons.

[2] Based on a product of fifty tons of pig iron per day.

Minimum labor cost per ton	$1.24
Maximum cost per ton	1.46
Average labor cost per ton	$1.35
Average salary charged per ton of pig iron	$45.00[1]

Salaries.

SUMMARY OF COSTS PER TON OF PIG IRON AT FURNACE.

	Min.	Max.	Aver.
Cost of two tons of ore	$2.14	$3.26	$2.70
100 bushels of charcoal	4.25	4.55	4.40
Limestone	.38	.42	.40
Labor	1.24	1.46	1.35
Salaries	.45	.45	.45
Oils	.05	.05	.05
Sand	.05	.05	.05
Tools and smithing	.15	.15	.15
Repairs	.25	.25	.25
Stationery	.05	.05	.05
Selling	.25	.25	.25
Interest	.25	.25	.25
Sinking fund	.25	.25	.25
	$9.75	$11.45	$10.60

Summary.

CONCLUSION.

As has elsewhere been pointed out, the abandoning of Pilot Knob has cut off one of the great sources of ore supply for St. Louis. If iron manufacturing is to be sustained there, a universal impression is that ores must be brought in from the Lake Superior region, or pig iron for the foundries must be brought from the same region or from Alabama and other southern furnaces. There are only two ways out of this. One is the finding of new and rich ore deposits in the porphyry region of the State; the other is to work the iron ores of southern Missouri in local blast furnaces and to ship the pig iron to St. Louis.

Future of Mis iron produc

In view of these facts set forth in this report it would seem to be well worth the time of iron masters of St. Louis and other places to look well into the extensive limonite deposits of southern Missouri.

[1] Based on an annual output of 15,000 tons.

PART II.

THE IRON ORE LOCALITIES.

A systematic description of the more prominent occurrences of iron ores in Missouri.

CHAPTER VIII.

INTRODUCTION TO PART II.

The preceding pages of this report have been occupied with generalizations based on facts gained by the study of individual mines. In the porphyry iron ores the conclusions in regard to the origin of the ore bodies, their nature and probable extent, are based on the study of deposits which have been extensively worked and thus thoroughly developed. The same may be said, though in a less degree, of the specular ore deposits in the region of the Roubidoux sandstone. In the limonite iron region the case is altogether different. These deposits have never been extensively worked and the few which have been worked were opened so long ago that little can be learned from the study of the old banks. Enough has been seen, however, to warrant the conclusions which have been drawn. The work of the Survey has been successful in calling attention to a great district of limonite iron ores the mere existence of which was hardly known up to the beginning of the present survey. Isolated deposits were known, and scattered localities were reported to abound with limonites. The accompanying map and the following descriptions of deposits will serve to call attention to the fact that there is a limonite district on the southwestern slope of the Ozark Uplift which is quite as pronounced as that of the specular ores of the sandstone belt, and, though not so valuable as the specular ores, their great abundance will in a measure compensate for this.

Hematite ores extensively worked.

Attention called to new localities.

Neither in the map or the detailed report has it been possible to notice every locality in which iron is found. It is therefore proposed to briefly point out some of the salient features of the different occurrences of iron, in the place of attempting a de- detailed description of each county. Without the most exhaus-

Only salient features pointed out.

tive examination, such as has not been possible with the means of the Geological Survey, this is impracticable in the case of iron ores.

The specular iron ores which occur in the porphyry region have been so fully treated of in the preceding special chapter, that the subject will be dismissed here with but a word. The porphyry belt is well defined, and, if further deposits of iron ores exist in the exposed portions of this rock, prospecting for them on the surface is a comparatively simple matter. The work which has been done with a diamond drill at the mines seems so far to hold out little hope for the finding of extensive vein deposits at these localities which do not now show. As was stated in the special chapter, however, surface prospecting has been very thoroughly done and with few or no practical results. The prospecting with diamond drills has so far only been done in connection with well known ore deposits. But if the hypotheses which were assumed are correct, then there is a fair chance of success in prospecting for veins which are apart from known deposits and which do not show on the surface. As an instance in point, a vein deposit was struck at the base of Shepherd mountain under the Cambrian rocks which gave no surface indications.

rospect- been bly

The specular ores of the sandstone region present a very different phase. The deposition of the specular iron ores of this region began soon after erosion commenced the wearing down of the Ozark Uplift. With the cutting of underground channels and the removal of lenses of limestone from the transition beds between limestone and sandstone, began a falling in of the soluble sandstone. At the same time and subsequently to this, the iron was being deposited.

posits ed by aining.

On account of the deposition of iron the rocks were indurated and were thus less acted upon than the unprotected rocks. Within certain limits the more extensive the erosion the greater the deposits of iron, other things being equal. Meanwhile, still bearing in mind that this area of the Ozarks was rising, we can imagine that erosion would cut deeper with the rising land. With this deeper cutting deposits of iron ore occurring on the border of some stream would be gradually undermined and allowed to glide down a slope or to sink into a ravine which had

been cut into the limestone and under the deposit; and, further, we can imagine that other deposits would remain comparatively undisturbed. The fact that such deposits of specular ore exist under the conditions implied above has been amply demonstrated both in the chapter on specular ores of the sandstone region and in the particular descriptions which follow.

Dependence of deposits of specular ore on the topography.

A fact which becomes very apparent in the study of these deposits is that the nature of a given deposit of specular ore depends largely, or at least is closely connected with the topography of the country. From the nature of the ore deposits, as described, and from the knowledge we have of their origin, we can easily infer what is actually true, that the best deposits and the greater number exist in the plateau region, and that, as we go from the plateau to where the drainage streams cut the slopes of the uplift into deep ravines, the deposits of specular ore become less and less distinctively deposits, but appear as scattered blocks of hard blue ore, until in the extreme mountainous country they almost wholly disappear.

Deposits of specular ore to be expected in the plateau counties.

From the above statement of fact it would appear to be reasonable to expect that, in the plateau counties of Dent, Crawford, Phelps and Texas, more extensive and regular deposits of specular ore would occur than in adjoining counties where the streams have cut more deeply and the country is more "mountainous." This natural surmise is borne out by facts. As we go away from the more level plateau region the deposits do grow more and more disturbed. Yet it must be borne in mind that, on the great divides between streams, there may be broad topped hills comparatively undisturbed upon which, or in which, large deposits of comparatively undisturbed specular ore may exist, as for example, the Rogers and Burt banks in Iron county. This, however, does not affect the main statement, that the best prospects for specular ore are in the plateau region.

Different conditions exist regarding limonite ores.

In regard to the limonite iron ores quite a different set of conditions exist. These ores were deposited long after the specular ores, many were no doubt derived from, and probably are even now being derived and deposited from them, as well as from other sources, at the present time. Unlike the specular ore deposits, the plateau region is not the most promising place for them.

They are found there, but they are limited in quantity and often poor in quality. Just what the exact relation is, is not yet made out, but it is a noticeable fact that association with sandstone is characteristic of the specular ores, and with limestone of the brown hematite. Another point is that the steep walled cañons, steep, cherty hills, in short the mountain region of the Ozark Uplift, is no more the habitat of limonite than of specular ore. There is this difference, however. Specular ore is never found in such places while limonite often occurs in large masses of remarkable purity, as for instance at the Old's bank in Oregon county. This bank, however, though it has thousands of tons, is, comparatively speaking, really small and unimportant as to size and the numbers in the mountainous region do not make up for this lack of size.

...lation of ...stone with ...ular ores.

Limonites are derived from rocks or from pre-existing deposits by solution, and they are deposited in a region of still waters. It would follow that in the region of quieter waters, where erosion has progressed farther and the steep walled hills have almost wholly disappeared, would be the most favorable localities for limonite. In any given locality, then, an estimate favorable or unfavorable for limonite in extensive deposits can be based on topography. Not on the summits of narrow crested divides, nor on their steep slopes, nor yet in the ravines, if they are narrow and steep walled, will deposits of limonite be found. On the sides or slopes of easy hills or at their bases is the most favorable locality. To any one who wishes to know whether a given locality is favorable for a deposit of limonite in the Ozark Uplift a careful study of the topographical map and sections of the Lamons bank is recommended.

...ation of ...nite ores.

One point to be especially borne in mind is this. Even in the mountainous part of the Uplift there may be large areas sheltered from the most rapid erosion and thus present conditions favorable to the development of limonite. Especially may these conditions be considered as favorable if the outcrop, instead of consisting of large boulders of ore and associated with rocks in place, consists of scattered fragments of ore of small size imbedded in a clayey soil. In general, however, the rule will be found useful, that no valuable deposits of limonite can

...e occur a ...s sheltered ...rapid ero-

occur in regions of great, steeped walled divides with narrow ravines.

The occurrences of the bedded red hematites has already been pointed out in the preceding pages.

Deposits of bog ore in the extreme southeast.

There have been from time to time reports of extensive deposits of bog iron ore in Scott, Mississippi, New Madrid, Pemiscot and Dunklin counties. In June of the present year these counties were visited by the writer. The reported localities were found but there was nothing to indicate that the deposits were extensive. The remnants of the hills of limestone are found on the land divides between the river but no rocks are in sight. There seems practically to be no source for the iron, and it is probable that only a few small chalybeate springs along the border of the swamps have produced all of the bog iron present. Of course this judgment is based entirely on surface observations, as no excavation has ever been done. But the whole contour of the entire region is against the existence of extensive deposits of bog iron.

Authority for the following descriptions.

In the following pages a brief description is given of all known localities of iron ore, and the approximate location is given on the accompanying map. The examinations of the localities which are described have been made either by myself or by my assistant, Mr. Elston H. Lonsdale. Of those localities which have not been operated since 1872, Dr. Schmidt's descriptions are incorporated and Mr. Phillip Moore's description of those not operated since 1873 are similarly quoted. The reported localities which are given without description are on the authority of the persons named.

In the report the examinations made by myself (Nason) are marked with (N.), those by Mr. Lonsdale with (L.), while the large number extracted in full or in part from Dr. Schmidt's report of 1872, are credited to him by an (S.), and those extracted from Mr. Moore's report of 1873–74 are marked with an (M.)

NOTICE. The descriptions of occurrences of iron ore in this and succeeding chapters are by counties, in alphabetical order, and in each county the occurrences are also described in alphabetical order.

CHAPTER IX.

THE SPECULAR ORES IN SANDSTONE.

CRAWFORD COUNTY.

BENTON CREEK MINE (S.).

Sec. 32, T. 36 N., 5 W.

A description of this mine was given by Dr. A. Schmidt in the Report of the Missouri Geological Survey, 1872, part I, p. 184. It has now been abandoned.

CRAIG MINE (N.).

Sec. 24, T. 36 N., 5 W.

The Craig bank is near the Meramec river and on the north side. It is also west of a small stream which empties into the Meramec. The western face of the hill on which the mine is situated is limestone in horizontal beds. Near the brook, sandstone, associated with the ore, occurs; both the sandstone and the ore dipping rather steeply towards the brook. Near the brook, and the railroad to Sligo, sandstone also appears dipping steeply. The ore body, as shown by mining, seems to be interstratified in irregular lenses in the slaty, impure limestone which lies under the sandstone. In other words, like many of the specular ore deposits, it seems to lie in the calcareous part of the beds of sandstone. Much of the sandstone is so highly charged with specular ore as to appear like a solid ore. The ore body as a whole is rather lean, and, owing to its irregular shape, is difficult to work.

FERGUSON MINE (S.).

Sec. 21, T. 37 N., 4 W.

A flat northern hill-slope here shows in several places, horizontal zones of larger and smaller fragments of specular ore on the surface. These zones are both distinct and indistinct. They are from four to eight feet wide, measured down the slope. They seem to run across the slope and to terminate on either side, in a ravine. The ravine on the western side is the deeper, and contains irregular accumulations of rounded ore. A shaft sunk, near the highest point of the slope, to a depth of twenty-two feet, passed through six feet of soil and

red loam, two feet of soft red hematite, two feet of red and yellow sandy clay, two feet of soft red hematite with pieces of specular ore, two feet of red clay with pieces of sandstone and some chert, and eight feet of large boulders of specular ore imbedded in soft red hematite, below which a layer of light yellow clayey ocher was struck. All of these layers seemed to be dipping into the hill.

GROVER MINE (S.).

S. W. ¼, Sec. 2, and N. W. ¼, Sec. 11, T. 35 N., 4 W.

This bank is situated on the top of a high ridge, with rather steep slopes, cut by numerous ravines, which descend gradually through lower ranges of hills into the broad valley of Crooked creek.

The ore does not lie thick, either on the slopes or on the hill. It is more concentrated in the ravines. The Third Magnesian limestone and the Second sandstone are met with in going from the valley up to the bank. The sandstone becomes very ferruginous near the bank. Above this is a thin streak of red clay with chert and, finally, the ore on the summit. The succession of rocks and the situation of the bank seems to warrant the presence of a good ore deposit, although the surface ore is not very copious. Six small shafts have been dug on the top of the hill, five of which were too near the outcrop of the ore, and therefore after cutting through five to seven feet of soft red and of specular ore, struck either the underlying white clay or the chert breccia or the impregnated sandstone. The sixth shaft was made nearer the central part of the summit, and struck soft, red hematite immediately below the soil, together with boulders of specular ore up to one foot in diameter. This shaft was discontinued at a depth of six feet, and is all in the ore.

IRON RIDGE MINE NO. 1 (S.).

N. E. ¼, Sec. 29, T. 39 N., 5 W.

The plan and section of this mine was given by Dr. A. Schmidt in the Report of the Missouri Geological Survey, 1872, Part I, p. 142. It has been abandoned.

IRON RIDGE MINE NO. 2 (S.).

Sec. 33, T. 39 N., 5 W.

Here, on an extensive tract of slightly undulating ground, are found in many places indication of specular ore, and occasionally large boulders of good surface-ore. A number of ditches were made to investigate this tract and disclosed irregular accumulations, mostly of small extent, of rounded ore with red clay, of white clay with pieces of chert and of impregnated sandstone.

OLD COPPER HILL MINE (S.).

E. ½, N. E. ¼, Sec. 23, T. 40 N., 2 W.

The ore occurs on a rather steep, and nearly isolated hill. The surface ore is specular in some places; pure, in others mixed with sand and passing into a strongly impregnated sandstone. The pieces are all rounded, usually only two

or three inches across. The two shafts sunk here, were sunk to a depth of perhaps twenty or thirty feet in loose sand and clay with pieces of white sandstone.

SCOTIA MINE NO. 1 (S.).

E. ½, S. E. ¼, Sec. 1, T. 38 N., 3 W.

A description of the mine is given in the Report of the Missouri Geological Survey, 1872, Part I, p. 128, by Dr. A. Schmidt. The mine is now abandoned.

SCOTIA MINE NO. 2 (S.).

S. E. ¼, Sec. 28, T. 39 N., 2 W.

A description of this mine is also given by Dr. A. Schmidt in the Report of the Missouri Geological Survey, 1872, Part I, p. 131. At present the mine is abandoned.

STEELVILLE MINE NO. 1 (S.).

E. ½, S. W. ¼, Sec. 5, T. 37 N., 4 W.

A description of this mine may be found in the Report of the Missouri Geological Survey, 1872, Part I, p. 152. It is now abandoned.

THOMPSON MINE (S.).

Sec. 26, T. 36 N., 4 W.

Considerable specular ore has been taken from this bank and smelted at Sligo furnace. The ore is mingled with chert and sandstone in the same way as at Cherry Valley. There is much secondary calcite present, which is stained by iron so as to resemble jasper. The ore body rests on limestone with broken sandstone as cap rock. The ore is rather lean.

DENT COUNTY.

[illegible] MINE (S.).

[illegible]

[illegible] thoroughly opened [illegible]. The ore is principally [illegible] of the ground reaching from the ravine about forty feet [illegible] of forty to fifty feet. On this ground large boulders [illegible] mostly rounded, are found, together with [illegible] sandstone, containing thin seams of specular [illegible] impregnated ferruginous sandstone are also quite [illegible] are exposed in the ravine. A [illegible] at the [illegible] clay, mixed with paint-ore [illegible] shaft twelve feet deep into the [illegible] through red, sandy clay. [illegible] sandstone and with boulders of [illegible] with sandy ferruginous [illegible] [illegible]

BLAIR MINE (L.).

S. ½, Sec. 9, T. 35 N., 6 W.

Here, across a ravine from the Williams bank, on the lower slope, are located an irregularly-shaped shallow cut and shafts, none more than twenty feet deep. The surface material is a chert and ore breccia mingled with blocks and fragments of hard sandstone and chert. From one shaft little else than sandstone was taken. This shaft is higher on the hill than are the other shafts and the cut. From each shaft clay containing chert and sandstone was removed. This area was but poorly prospected. A considerable amount of fine, soft, red ore with a small amount of blue specular ore has been shipped from this bank; but it is now abandoned.

FITZWATER MINE (S.).

Secs. 33 and 34, T. 34 N., 4 W.

This mine occupies a pretty high position, being about four hundred feet above the Fitzwater creek. It lies in the northwestern slope of a ridge which is composed of Third Magnesian limestone capped by Second sandstone. A sandy soil, mixed with fine and coarse pieces and masses of chert, covers the surface of the hills. The ore occurs over one large central spur, and over the adjacent slopes of two spurs, north and south of the central one. The best indications extend about fifteen hundred feet north and south and about eight hundred feet east and west. Most of the ore is rounded off at the corners and edges and is usually about three inches across, sometimes larger. The ore seems to be most abundant at a certain level along the slopes, which level is about eight feet below the highest point on the two northern spurs, which are flat and low. The southern spur is considerably higher and the level of the most abundant surface-ore is there much farther below the highest point.

HAWKINS MINE (N.).

Sec. 11, T. 35 N., 6 W.

This bank is crescentic in shape, but work now being done seems to indicate that the horns of the crescent will meet, thus making the bank circular. It occurs on a plateau which is considerably raised above the surrounding country. As is usual with the specular ore banks the sandstone, when exposed, dips toward the ore body. Broken sandstone and chert with interstitial specular ore occur. The ore body proper has considerable limonite, which has probably been derived from the specular ore by hydration. The ore occurs in large lenticular masses with lenses of colored clay. There is a great deal of specular ore which is *plumose and botryoidal*, seemingly pseudomorphous after pyrite, though pyrite has not been found in large quantities.

The whole appearance of the bank leads to the idea that the mine began as a lime sink. This theory at least explains the circular shape of the deposit and the concentrically dipping sandstones.

[illegible]

[illegible] on all sides by deep ravines. [illegible] from Simmons mountain in this, that [illegible] the hill is cut out from the plat- [illegible] The surface of the hill is cov- [illegible] limestone [illegible] Mingled with this sur- [illegible] One shaft 30 feet [illegible] through [illegible] decomposed cherty [illegible] away from the hill. Beneath this [illegible] limonite and soft red hema- [illegible] gone through the ore. Another shaft [illegible] the same rela- [illegible] the entire body of [illegible]

[illegible]

[illegible] mostly rounded, is [illegible] west and south sides of a high ridge. But [illegible] The hills are covered with soil and chert. [illegible] are found on the lower part of the [illegible]

[illegible]

[illegible] waters of the Meramec from [illegible] on the highest point on a rather [illegible] depression, apparently [illegible] ore. The ore is in [illegible] two or three feet in [illegible]

[illegible] is seen about six [illegible] small ravine to the south. [illegible] feet through red, sandy [illegible]

[illegible] MINE [illegible]

[illegible]

[illegible] particles to masses six or eight inches across, [illegible] about thirty feet high, with sandstone colored and im- [illegible] The argillaceous or calcareous cement that sur- [illegible] changed into red clay and reddish-brown iron

PLANK MINE (N.).

Sec. 33, T. 35 N., 6 W.

This bank differs in no material respect from the Hawkins bank and the Simmons mountain deposit. The mine is encircled on all sides by a low ridge. The workings of this mine shows that the dip, both of the clay and slaty rock and sandstone as well, is towards the ore body. No limestone is in sight at the mine or in the immediate vicinity. Two deep shafts have been recently sunk on the southeastern and the southwestern sides of the mine. A drift connects the two shafts at the bottom. The drift seems to be wholly in ore. The entire working ore body is now underground.

The ore is of the usual variety of specular ore. It is mingled with limonite which occurs occasionally, but it is not as abundant as when the ore was taken from a higher level. Jasper and vugs of quartz and amethyst are met with in the ore. There is much soft red ore present.

POMEROY MINE (S.).

Sec. 10, T. 34 N., 6 W.

Here the principal mass of surface-ore, although in large quantities and sizes, is not on the summit but on the western slope, where indeed, besides the cherty soil, hardly anything else but ore is seen on the surface. The summit is occupied by ferruginous clay-rock and pieces of ore altered into limonite. On the eastern slope there is a zone of well-known breccia of white chert, cemented by clay-rock, and lower down the ordinary, white or yellow Second sandstone.

SLIGO MINE (N.).

Sec. 2, T. 35 N., 4 W.

There has been a good deal of ore taken from this bank but the deposit seems to have been rather "pockety." The surface of the ground is covered with broken sandstone and the ore seems to have laid in lenses in the slaty limestone immediately under the sandstone. The ore body lies on a ridge about 100 feet above the furnace at Sligo. Two drainage streams flow towards the valley from either side of the ore body. Toward these the sandstone dips steeply. On the west side of the ore body, as now known, a shaft is being sunk. It has penetrated almost 50 feet in loose saccharoidal sandstone, with no ore in sight.

It is intended to sink at least 100 feet or until limestone is struck. Drifts will then be run in various directions. This promises to be one of the most thoroughly tested mines of the specular ore region.

TAYLOR MINE (S.).

S. W. ¼, S. W. ¼, Sec. 12, T. 34 N., 7 W.

This whole mine is situated on the slope, and the specular ore occupies the foot of the hill. The surface ore extends over an area about four hundred feet square. The main body of the ore will probably be found in the upper part of the semi-circular space, which is surrounded by a zone of ferruginous rocks.

WILLIAMS MINE (L.).

N. ½, Sec. 16, T. 35 N., 6 W.

The Williams mine was owned and was operated by the Midland Blast Furnace Company. The mining was done on the point and western slope of a spur leading off from the main ridge. A cut about fifty yards long, north and south, and sixty yards wide, and several shafts of various depths have been made here. The deepest of these shafts extended to a depth of thirty feet. In this one red clay, a good quality of yellow ocher, a small amount of ore and chert fragments and strata were met with. In the southern end of the main cut which is also about thirty feet deep, a prospect hole ten feet deep was put down and passed through only a small amount of ore.

The walls of the cut now show ocher, irregular strata and blocks of chert, clay, some ore and detrital material. A larger amount of ore extended from the surface to the bottom of the cut.

The greater portion of the ore is of the red variety with a variable amount of hard specular ore mixed with it. This bank is now abandoned.

FRANKLIN COUNTY.

THURMOND MINE (S.).

N. ½, N. W. ¼, Sec. 19, T. 41 N., 1 W.

This mine is situated in a rather rough country, with steep, high hills, separated by narrow ravines and valleys. The soil is mixed with and in some places covered by broken, white chert. The surface indications consist of a number of large pieces of limonite, and of some small, sharp fragments of a very hard and siliceous specular ore. They are scattered over a surface about fifty feet wide and two hundred feet long, over a slight rise of the ground extending down the slope of a moderately steep hill. A shaft was sunk here years ago in search for copper, and it is said this shaft passed through thirty-seven feet of red iron ore.

IRON COUNTY.

BURT MINE (N.).

Sec. 2, T. 34 N., 1 W.

This bank occurs on the slope of a ravine, not on the summit of a hill. Two trenches have been cut out in the slope and each has struck a body of soft red specular ore, and has followed it up the slope for fifty feet or more. The trenches show that the ore body dips regularly with the slope of the ravine. The whole of the ore body is soft and greasy to the feel, even the harder and less decomposed lumps. These are "slickensided," and, in fact, the whole ore body shows slickensides. There are masses of jaspery ore which is not, of course, so badly decomposed. There are also "vugs" of quartz and amethyst crystals. The whole bank presents the appearance of a specular ore deposit which has

been undermined and has been caused to slide bodily down the hill-side. There have been comparatively few openings made but these seem to show signs of a very promising deposit of specular ore.

RED POINT LAND (S.).

Secs. 14 and 15, T. 34 N., 2 W.

Here the top of the ridge is broad, the slopes dip very gradually and over the surface, blocks and fragments of hard bright sandstone with scattered pieces of chert occur. On the slope in two or three localities, fragments and boulders of specular ore are found. The largest would weigh seventy-five or one hundred pounds. The ore is hard and portions of it contain grains of white quartz. On the whole the ore is of a very good quality. No work has been done here to prove the occurrence or non-occurrence of underground ore.

No bedded rock is exposed near the surface ore.

ROGERS MINE (N.).

Sec. 2, T. 34 N., 1 W.

This bank is situated on the summit of a high divide between two forks of Black river. The only rocks in sight are blocks of broken sandstone. Fragments of specular ore occur on the surface and also imbedded in the clayey soil. Limestone is found in horizontal beds in the ravines. Several small openings have been made. All of them show regular deposits of specular ore. The ore occurs in layers which are broken into boulders and these boulders have been almost entirely changed into a soft red crystalline ore. The openings show that the sandstone and decomposed chert beds dip steeply down the slopes of the hill. The openings are not deep enough, nor are they made in such a manner as to expose the deposits in a favorable light. Yet from the extent of the deposit as indicated by the openings, from the fine quality of the ore, its soft nature showing that it has been little disturbed, it is quite probable that the deposit is a valuable one.

REPORTED LOCALITIES.

Mr. A. H. Eaton reports the occurrence of specular iron ore in T. 34 N., 1 E., Sections 7, and 15; in T. 34 N., 1 W., Sections 1, 12, and 27; in T. 34 N., 2 W., Sections 1, and 14; in T. 35 N., 1 E., Sections 20, and 32; and in T. 35 N., 1 W., Section 35.

MONTGOMERY COUNTY.

RED HILL MINE (N.).

Sec. 17, T. 50 N., 3 W.

Boulders of specular ore are mingled with fragments of sandstone, chert and limonite, and all these, imbedded in red clay, lie on the summit of a hill 130 feet above the level of a brook. The outcrop is not extensive, and no development work has been done.

PHELPS COUNTY.

AFRICAN MINE (L.).

Sec. 22, T. 36 N., 6 W.

This mine is situated in the lower slope of a long ridge, near [illegible]. The slope is quite gradual and the surface bears blocks of [illegible] sandstone and large and small fragments of chert.

In mining the ore a cut, perhaps twenty yards in diameter and about twenty five feet deep, was formed, and in addition to this cut, several similar shafts were sunk. Here, below the surface, is a four-foot [illegible] layer of soft red ore of good quality. In the northern end of the cut a mass of sandstone with some chert with a small amount of red ore makes up the entire [illegible]. This sandstone and chert occurs in different portions in all walls of the cut.

Considering the size of this cut, the amount of red ore with some specular masses which have been taken out and shipped, is large. The mine has been abandoned for several years. It was owned and operated by the [illegible] Iron Company.

BEAVER CREEK MINE (S.).

S. ½, Sec. 33, T. 37 N., 8 W.

The Beaver Creek mine lies on the summit of a high ridge, near the head of Beaver creek. The ore seems to be pretty solid, and in great part specular, but slightly altered or softened. It extends about seventy feet from north to south, being cut off on both sides by nearly vertical layers of green clays, imbedded in red loam. Next to this a layer of chert breccia may be observed on the northern wall.

BUCKLAND MINE (S.).

S. ½, Sec. 29, T. 37 N., 8 W.

This mine lies at the foot of a hill at the crossing of two ravines. On the south side of the cut is found a mass of black, tenacious clay, mixed with fragments of a half-decomposed, dark gray clay-shale, with pieces of pyrites, and impregnated with sulphate of iron.

[illegible] MINE (L.).

Sec. [illegible], T. [illegible] N., [illegible] W.

This mine is situated near the summit of a long range of hills on the western slope. Here there is one principal cut with shallow shafts and a small cut [illegible]. The large cut was about [illegible] feet deep, sixty yards long and fifty yards wide. Some detached masses of [illegible] specular ore are found lying on the surface and [illegible] and red ore were taken from the cut. The walls of the mine are washed and caved in but show a large amount of chert, in large and small pieces, with [illegible] sandstone and lime and red [illegible] ore. [illegible] with a small amount of limonite is also found in the mine.

JAMES MINE AND MOSELLE MINE NO. 9 (S.).

S. ½, S. E. ¼, Sec. 29, T. 38 N., 6 W.

These two mines are situated close together, on a low ridge, on the plateau of St. James, between the Dry Fork and the Bourbeuse rivers.

This deposit is formed in connection with the Second sandstone and Third Magnesian limestone.

Both of these banks are nearly worked out; the best and richest ores are all taken out, and the walls and the bottoms of the deposits are laid bare. The ore formerly contained in these pockets was mostly soft, red, and in part greasy hematite, enclosing large boulders of specular ore.

KELLY MINE NO. 1 (S.).

E. ½, Sec. 18, T. 36 N., 8 W.

This mine is situated near the summit of a hill. The bank resembles the Thornton bank, but seems to be more extensive and contains larger pieces of hard specular ore. There is next to the ore on each side, a thick layer of white clay mixed with broken chert, and outside of this a mass of yellow sand and red loam, irregularly mixed and free from chert.

KELLY MINE NO. 2 (S.).

N. E. ¼, Sec. 21, T. 37 N., 8 W.

Here two openings have been made, one on the summit and another on the eastern slope of a hill. The lower opening shows a double succession of layers of clay, of broken chert and of broken ferruginous sandstone dipping southeastward and below this an irregular mass of soft hematite, red and brown, containing thin veins and small pockets filled with crystalline carbonates of iron. These carbonates are also found as cement of broken chert. The large mass of loose gray rock on the north side of the cut contains single crystals of iron pyrites and also veins of carbonate of iron.

The upper opening shows a bed of boulders of limonite some six inches in diameter, imbedded in loam without any chert.

LAMB MINE (S.).

Sec. 35, T. 36 N., 6 W.

This mine is situated on the dividing ridge between the Benton creek valley and the Norman Hollow, at the head of the western branch of Benton creek.

The main part of the branch is situated close to the highest point, and is nearly round, one hundred and fifty to two hundred feet in diameter. No distinct annular outcrops are perceptible, however, and the limit of the body of massive ore can therefore not be determined with great accuracy. But an annular streak of ferruginous clay-rock and of chert breccia can be traced nearly all round the bank, from the loose pieces lying on the surface. A horizontal outcrop of white sandstone is found half way down the western slope where also large boulders of specular ore occur, as well as in the western ravine

which is about one hundred and thirty feet below the bank. The low, triangular slope south of the circular bank is covered with small and rounded surface ore. This ore was undoubtedly washed down from the main deposit.

SANTEE AND CLARK'S MINE (S.).

S. W. ¼, Sec. 33, T. 38 N., 6 W.

This mine lies on a high bluff of Third Magnesian limestone and Second sandstone, on the east side of Dry Fork river. Several openings have disclosed irregular masses of red and brown ore.

SMITH MINES (S.).

Sec. 26, T. 36 N., 6 W.

The three Smith mines are situated on very flat slopes or swellings of the ground, all pointing south, and lying about on an east-west line, within a distance of one-half mile. The two western banks are very near together, and have a very similar appearance. In both of them good specular ore in very numerous rounded pieces, is spread over a flat, triangular slope, encompassed by two small triangular ravines, which unite at the southern end of the bank. The upper, wider and most northern part of the slope, which forms the base of the triangle, passes into a plateau. This triangular space, over which the ore extends, is about two hundred and fifty feet wide at the base and three hundred feet long on the western bank; it is two hundred and fifty feet wide at the base and six hundred feet long in the central bank. The ore of the latter is somewhat smaller than that of the former, which sometimes reaches eight inches across. Pieces of broken chert and sandstone are found with the ore. The western bank extends twelve to twenty feet over its western ravine and up the opposite slope, where the ore, however, has a somewhat different character, being mostly stalactitic, or pipe-ore. Holes dug in this bank passed through loose masses of broken white sandstone, sand, broken chert, white clay and red loam, all mixed irregularly, and containing in places some soft red hematite and some rounded specular ore, the latter principally contained in the soil near the surface. The third bank has a different appearance. On the upper part of a flat slope a circular depression of sandstone is perceptible, having a diameter of about fifty feet, and being marked by annular outcrops. Inside of these outcrops is a small accumulation of specular ore, in rounded pieces.

STIMSON MINE (L.).

Sec. 10, T. 36 N., 6 W.

Here a cut sixty yards long has been made in the bottom of a ravine which lies between two hills of moderate slope. In the western portion of this cut the mining was prosecuted to a depth of twenty feet beneath the surface. On the surface here hard specular ore was found mingled with chert fragments. A considerable amount of good red ore was shipped from this locality and there now remains some ore stocked at the bank of the cut. The walls of the cut are mostly of white stratified siliceous clay and bands of decomposed and non-decomposed chert and sandstone interlaminated with red clay and irregular

masses of red ore. Only a small amount of ocher is seen in this mine. The ore-vein proper was said to dip in the direction of the slope of the ravine. Near this cut a thirty-foot shaft was sunk and at the bottom, red ore of good quality is said to have been found. About fifty yards down the ravine, on the slope of the ridge, another cut was made into the hill to a distance of forty feet. The floor at the mouth of the cut is of bedded sandstone, and some loose masses of sandstone are found in the sides at the same point. Clay, chert and sandstone appear in the sides. The inner end of the cut is half made up of brown and blue ore cementing fragments and boulders of chert. No work has been done in either localities since 1880.

TAYLOR'S ROLLA MINE (S.).

S. W. ¼, Sec. 15, T. 37 N., 8 W.

This mine is situated a short distance from the Kelly bank No. 2. The bottom of the cut consists of a bed of finely broken chert. Above this is a layer, three feet thick, of soft red hematite, in part clayey, and full of seams, specks, and irregular masses of spathic iron ore, and enclosing boulders and pieces of specular ore and chert. Above this are five feet of alternate layers of red, somewhat ferruginous sandstone, and of red loam with broken chert. A cherty soil covers the slope.

THORNTON MINE (S.).

N. E. ¼, Sec. 33, T. 38 N., 6 W.

The ore here occurs with red and white clay and with white chert and yellow and red sandy clay. It is soft red, with small pieces of hard specular ore. No large boulders have as yet been found.

WILLIFORD MINE. (L).

Sec. 36, T. 37 N., 6 W.

This mine is on the point of a large hill with moderate slopes, covered principally by large chert fragments, but also by blocks of sandstone. The cut from which the ore was taken is sixty feet long, twenty feet wide and apparently rather shallow. No section is here obtainable. On the surface are bodies of good red ore with chert and hard sandstone and brecciated brown ore, which have been removed from the cut. A few shallow pits, dug near the cut, show hard sandstone and chert, but a very small amount of ore. It is reported that all of the ore taken from this mine still lies on the bank of the cut. The mine has long since been abandoned.

WINKLER MINE (S.).

S. ½, Sec. 14, T. 36 N., 6 W.

This mine is situated on the plateau between West Benton creek and Norman Hollow, and spreads over three flat hills, lying in a north-south line. The southeastern slope of the most northern of the three hills is covered with good and large surface ore, mixed with broken chert. The central hill shows scarcely any ore on the surface. The southern hill is very wide and flat, and

bears on its western slope a very extensive streak of surface ore, about twelve hundred feet long and one to four hundred feet wide. Most of the ore is rather small and rounded off. The ore at the south end is very hard and siliceous, that at the north purer and softer.

REYNOLDS COUNTY.

JANUARY MINE (L.).

N. E. ¼, N. E. ¼, Sec. 20, T. 32 N., 2 W.

This mine of specular ore is situated on the extreme western limit of Bee Fork of Black river. The eastern slope of the hill here is very gradual and it is on this slope that the ore was first seen here. Here several small pits have been dug and, in each case, iron ore was taken out. One shaft was dug twelve feet deep and the lower seven feet was seen to be made up solely of iron ore; then a hole bored twelve feet deep into the bottom of this pit, continued to pass through ore. The ore can be mined with a pick; it weathers into a red, clayey mass. Within this softer ore are found scattered masses of typical specular ore. These masses contain some quartz and are partially composed of jasper. The quality of the red ore is very good. Some sandstone blocks and fragments are seen on the surface of the hill.

REPORTED LOCALITY.

Mr. A. H. Eaton reports the occurrence of specular iron ore in Sec. 8, T. 33 N., 1 W.

TEXAS COUNTY.

ROGER'S MILL LAND (L.).

N. W. ¼, N. E. ¼, Sec. 23, T. 31 N., 9 W

On the property of the Missouri Iron Company.

Specular iron ore occurs here near the top of a high spur next to Arthur's creek. The ore is in pieces, mostly small, though a *few* are as much as six inches across. It is somewhat siliceous, bearing silica in the form of drusy quartz or grains of sand. Next to the creek this spur is very steep, and sandstone, in horizontal ledges, is shown. Scattered fragments of the ore are to be found with this sandstone but it is said that these fragments were carried by rolling logs, from the deposit on the top of the hill. The main exposure of the area covers perhaps twenty square yards. Within this area a shallow pit was dug and from this pit fragments of specular ore and red, sandy clay were taken out in which were found scales of specular ore and a little red hematite. Chert fragments, large and small, are found in the surface of the hill around the ore area. Some of these are coated with limonite ore. Bedded sandstone is seen still higher up the hill, a short distance away.

WASHINGTON COUNTY.

BLANTON SPECULAR MINE (S).

N. ½, S. E. ¼, Sec. 29, T. 40 N., 1 W.

Some rounded surface ore, mostly small, is found here, on three spurs of a low ridge. The spurs point about north and strata of solid sandstone crop out at the foot of each. A hole, dug fifteen feet deep on the top of the most eastern spur, passed through drifted, sandy detritus, with little ore, then struck a layer of chert. This bank is on a hill thickly covered with detritus, through which single pieces of specular ore are unequally distributed. The ore itself is of good quality.

PRIMROSE HILL MINE (S.).

S. W. ¼, N. W. ¼, Sec. 32, T. 40 N., 1 W.

This mine is of similar character to the Blanton bank. The surface ore, mostly small and rounded, occurs on the inner side of a high horse-shoe shaped ridge, enclosing a deep ravine. Pieces of hard sandstone, with quartz cement, and of ordinary soft sandstone, are also found on the surface. The ridge was investigated by three shafts, one on the northern slope of the western spur, the others on the inner slope of the central and highest portion of the horse-shoe. Neither of these shafts reached solid rock. The two upper shafts are forty feet deep, in fine, sandy detritus, mixed with streaks and irregular masses of soft, red hematite and of broken stalactites or half decomposed specular ore, sometimes cemented by soft sandstone.

CHAPTER X.

THE LIMONITES.

BENTON COUNTY.

CARPENTER BANK (S.).

Sec. 19, T. 40 N., 21 W.

Limonite covers the surface here over only a small area, of perhaps twenty feet in diameter, but is found scattered in less quantity in various other places on the same hill. There is no ore in the strata of the cut, it is found only in the soil covering the strata. Limestone is found under the surface loam and clayey sand, with white chert, in a thin distinct layer.

ELM HOLLOW BANK (S.).

Sec. 36, T. 41 N., 22 W.

The limonite at this place lies upon the northern slope of a hill over a surface, perhaps, fifty by one hundred feet. It consists of numerous angular pieces varying in size. There is a core of pyrites in some of the larger pieces of ore. Chert is scattered over the entire hill, and near the top, above the ore, occur pieces of sandstone.

GRISSOM BANK (S.).

Sec. 28, T. 40 N., 21 W.

Limonite is here in large pieces of irregular shape, very porous, partly of stalactitic fracture. The ore lies upon the western slope of a hill, one hundred and fifty feet high. At the foot, limestone is seen in position to a height of sixteen feet. Above this the mass of the hill seems to be sandstone, covered with pieces of sharp-cornered chert. Some of the ore is sulphurous. A singular feature of this bank is the appearance of the ore in large quantity and exclusively above the sandstone outcrops.

GUN BANK (S.).

Sec. 33, T. 40 N., 20 W.

Here a large amount of surface limonite is scattered for a distance of fifty feet vertically and five hundred feet along the northern slope of a low, flat hill. Two test-pits and numerous drill holes have been sunk, all of which struck the ore at a depth of four to six feet below the surface. The ore is of a good quality.

INDIAN CREEK BANK (S.).

Sec. 26, T. 42 N., 21 W.

Here there is a hill about two hundred feet high. At the base and extending probably twenty feet vertically, is a horizontal limestone. Above this, on the western slope, the surface is covered with chert and pieces of limonite. At one place is a large boulder of many tons weight. It is partly formed of fine pipe-ore broken, and the pieces cemented again by ore. Other pipe-ore is mixed with the soil near by. Sandstone probably forms the top of the hill above the limestone.

RICHWOODS BANK (S.).

Secs. 3 and 4, T. 39 N., 22 W.

The limonite here lies upon the western slope, in a belt about ten yards wide, and extending some two hundred feet up the hill.

Above the ore is a yellow sandstone. At the foot of the hill, a few hundred yards distant from the deposit, is an outcrop of limestone.

WALKER BANK (S.).

Sec. 36, T. 41 N., 20 W.

Here at the top of a high, cherty hill, single limonite pieces are widely scattered over an area twenty feet in diameter. The outcrop consists of large boulders of limonite of good quality.

BOLLINGER COUNTY.

BOLLINGER (B. H.) LAND (L.).

Sec. 31, T. 29 N., 9 E.

On the property of Mr. B. H. Bollinger, limonite is found in the form of broken masses, covering about sixty square yards on the point of the spur of a ridge. It is siliceous, silicia occurring principally as small broken chert fragments. The ore masses are usually small and angular and mingled with a few fragments of chert. On the surface surrounding the ore area, these fragments are more numerous. This locality is less than one mile distant from the Brownwood, Zalma Branch Ry.

DEAL BANK (S.).

Sec. 2, T. 31 N., 8 E.

Here is what is known as the Deal Bank. There are four successive layers, sloping with the hill. The lowest is a mass of solid, chocolate-brown limonite, taking occasionally a bluish color. It is in part mixed with yellow ocher, in part with white or yellow, fine or coarse, broken chert. The layer above the ore is red clay, with broken veins of ore which enclose broken chert; above

this is a yellow, sandy clay, mixed with fine chert, and interstratified with layers of this chert; above this is a cherty soil, with boulders of good, hard, dense limonite.

DONDORE (L. T.) LAND (L.).

Secs. 7, 8, 17 and 18, T. 28 N., 8 E.

Limonite is found in several localities within these sections. In one locality the ore occurs as huge, partially uncovered masses and fragments covering an area more than one hundred yards long and nearly fifty yards wide. This ore lies on a very gradual slope with chert fragments on the surface. At the extremities of this area some digging has been done. Here the surface masses were most numerous and largest. The surface ore is of a better quality than that towards the bottom of the cuts, which are four or five feet deep. In these cuts are found limonite, turgite and perhaps other varieties of iron oxide. The lower portion is quite sandy and contains nodules of insoluble material. Ore such as is found here is found about half a mile westward. These deposits are nine miles from Zalma at the extremity of the B., Z. Br. Ry.

GILMAN BANK (S.).

N. W. ¼, Sec. 1, T. 31 N., 8 E.

Here the mass of limonite ore is of lenticular shape and lies imbedded in yellow clay, mixed with fine, white chert. The ore is broken and fractured into pieces and blocks. The soil here is covered by, and encloses a large quantity of chert mixed with fragments of white sandstone. Limestone is seen cropping out in the bed of Crooked creek, one-half mile from this ore bank.

LEMON (THOMPSON) LAND (L.).

S. ½, Lot 3, Sec. 30, T. 29 N., 9 E.

This land is owned by Mr. Thompson Lemon. Massive limonite is found here in a ledge and in boulders and fragments. These almost wholly cover an area about forty yards long and thirty yards wide and are scattered over an area one hundred yards long and thirty yards wide. on the southern and eastern hill slopes, just north of a slight divide between two chert ranges. Only scattered boulders are found in the easternmost portion of this deposit. The ore is siliceous, silica occurring principally as fragments of chert, but also as disseminated grains of sand. This chert could be, to a large extent, removed by cobbing. Fragmental chert is found on the surface of this and neighboring hills. This locality is two or three miles distant from the B., Z. Br. Ry.

LUTE'S (JESSE) BANK (M.).

N. E. ¼. N. W. ¼, Sec. 11, T. 30 N., 9 E.

At this place the ore had been disclosed by two cuts on the northern slope of a hill, near the top. Scattered over this hill and the next one north, and occurring in the clay and chert at the cut, are found large numbers of hollow concretions of good ore. The main cut is thirty feet deep and shows

an extremely irregular mass of ocherous, cherty ore. Much ocher is associated with the ore. Lying above the ore is found, in irregular pieces, a peculiar, siliceous, red ore.

MURDOCH BANK (S.).

Sec. 16, T. 30 N., 9 E.

The limonite of this bank is found scattered thinly over a surface of two or three acres, on the top of a flat hill, and extending somewhat down the western slope. Near the top the ore is impure, being mixed with a breccia of flint, the ore serving as the cement. On the slope the ore grows purer and scarcer. There has been considerable prospecting done here, by scattered diggings and a shaft, but without disclosing anything but clay and chert.

MYER'S BANK (M.).

S. E. ¼, N. E. ¼, Sec. 32, T. 30 N., 8 E.

Limonite is found low down upon the hill. It lies closely along the very foot of the hill for about one hundred feet, in large boulders that seem almost solid. A little prospecting has been done at two places, by means of small cuts, which have revealed the presence of large boulders of ore underneath the surface. The ore is comparatively free from chert and other impurity.

NIFONG BANK (M.).

S. E. ¼, Sec. 2, T. 31 N., 8 E.

Two large cuts have been made here in the top of a high hill. The larger of these cuts, of irregular shape, is about thirty feet deep. Ore is seen here in an irregular mass eight or ten feet thick and about twenty feet long, inclined toward the west at a high angle, overlaid by a mass of reddish clay and chert, which shows semi-stratification in about the same direction. The ore at the south end of the cut is of good quality, a dense limonite and comparatively free from chert. That exposed on the east wall is very cherty. This cut is about a quarter of a mile from the Belmont Branch, St. L., I. M. & S. Ry. About one hundred and twenty-five feet, just over the top of the hill, another cut has been driven about sixty feet long and twenty feet deep at the head, where it has exposed a mass of very cherty ore six to eight feet thick.

POBLICK'S BANK (S.).

Secs. 23 and 24, T. 32 N., 8 E.

Hard limonite occurs here imbedded with white chert and pieces of sandstone in the soil and subsoil on the southern slope of a high and steep hill. No limestone is seen in this vicinity.

REVELLE (J.W.) LAND (L.).

N. E. ¼, S. W. ¼, Sec. 10, T. 29 N., 9 E.

Limonite is found here over about one hundred and fifty square yards. It occurs as large and small fragments on a moderate slope with but few pieces

of chert. Into this slope a cut seventy yards long has been made. This cut shows masses of limonite, a foot or so across, occurring in clay, from the surface to the bottom of the cut, which is ten or twelve feet deep at the upper end. This ore is but slightly siliceous, containing just a few small, scattered fragments of chert. This locality is about four miles distant from the B., Z. Br. Ry.

RHODE'S BANK (M.).

S. W. ¼, Sec. 14, T. 31 N., 8 E.

Limonite is found here in the form of boulders and fragments on the southeast slope of a low hill covering an area about two hundred and fifty feet long and fifty feet wide. It has also been exposed by two cuts. The upper cut reveals nothing but pieces of ore in the chert and clay. At the lower, is exposed over an irregular area, perhaps forty feet in diameter, ore, chert and a porous quartzite with cavities filled with ocher to which a small quantity of ore is found adhering. The surface of the hill above is covered with large boulders of ore and chert. At the upper cut the ore is better, but the same quartzose rock is found adhering to it.

ROBBIN'S BANK (M.).

Sec. 10, T. 31 N., 9 E.

Here, limonite occurs upon the northern slope of a high hill on the divide between Hurricane and Crooked creeks. It lies in many broken pieces of uniformly large size in a belt about two hundred yards long, north and south, and seventy-five feet wide. It is dense, hard, siliceous rather than cherty, and most of it is dark red in color. There are many chert pieces scattered with the ore on the surface.

TIBB'S BANK (M.).

S. W. ¼, Sec. 29, T. 31 N., 10 E.

Upon the northern slope of a hill about sixty feet high, limonite is exposed by a cut at the forty-foot level. It is seen at the head of the cut, which runs in a southerly direction, lying in broken, irregular mass much mixed with ocher, and imbedded in the clay. There is but little chert present, but the ore is full of ocher, and is occasionally sulphurous. Much ore is scattered over the surface, and several small test pits have been dug without revealing the presence of any solid body of ore.

TURKEY HILL (S.).

N. W. ¼, Sec. 32, T. 31 N., 10 E.

Limonite is found here, in the form of large and small boulders, at the foot of a steep hill, near the bottom of a ravine. These boulders are generally of a pure, dark colored limonite, which are imbedded and irregularly distributed through a yellow, marly clay containing much chert. A tunnel has been run about twenty feet into this hill, through clay containing ore-boulders.

REPORTED LOCALITIES.

Mr. J. H. Grant reports limonite as occurring in Sec. 25, T. 29 N., 8 E.

Mr. M. Hindman reports limonite as occurring in the E. ½, S. E. ¼, Sec. 9, N. W. ¼, S. E. ¼, Sec. 21, and in Sec. 28, all of T. 29 N., 9 E.

BUTLER COUNTY.

AGRICULTURAL COLLEGE LAND NO. 1 (L.).

Sec. 21, T. 26 N., 6 E.

This land is the property of the State Agricultural College. The limonite here covers an area fifty yards across. The ore is in the form of small masses, on the crest and sides of a divide, between two knolls. There also appears, cropping out at the lower margin of the area, a ledge of ore, the thickness of which is not shown. This ledge is only a few feet above a bed of limestone, which is exposed here. The ore is of a good quality, containing little or no siliceous matter. Some scattered chert lies within the area bearing ore and much chert and small blocks of sandstone are found on the knolls adjoining this divide. This deposit is located about one mile from the St. L., I. M. & S. Railway.

ALLEN BANK (M.).

W. ½, N. W. ¼, Sec. 4, T. 24 N., 6 E.

This bank of ore lies along the western slope, some three hundred feet or more, and is perhaps fifty feet in width. It occurs in pieces of various sizes, but shows no solid mass. In quality it is porous and sandy, but not enough so as to render it worthless.

BLUE SPRING BANK (M.).

S. E. ¼, S. E. ¼, Sec. 26, T. 26 N., 7 E.

Here the ore is found in large and small pieces, and in one place in a solid bed, overlying an outcrop of ten feet of Third Magnesian limestone, which shows at thirty feet above the bottom of the hill. The ore is in an outcrop about seventy-five feet along the slope, and thirty feet wide. It is quite sandy.

GOVERNMENT LAND NO. 1 (L.).

S. E. ¼, S. E. ¼, Sec. 24, T. 25 N., 4 E.

Here the limonite covers an area about thirty yards square, on a bench on the slope of a chert covered hill. The ore is but fair in quality, being slightly siliceous, silica occurring as chert. Within the area little else than the ore is seen, but on all sides are many chert fragments. The St. L., I. M. & S. Ry. is about thirteen miles from this deposit.

HENDRICKSON (N. W.) LAND (L.).

Sec. 20, T. 26 N., 6 E.

Semi-massive and stalactitic limonite is found here in small masses and boulders strewn over an area about seventy yards square on the slope of a knoll. The ore is but slightly siliceous and the boulders are mingled with scattered fragments of chert and small blocks of sandstone, with no bedded rock exposed near by. This locality is less than one half of a mile distant from the St. L., I. M. & S. Ry.

INDIAN CREEK BANK (M.).

N. W. ¼, Sec. 35, T. 26 N., 6 E.

At this place the ore lies upon the top and down the slope of a low hill, not over fifty feet in height. Ore is spread thinly over an area perhaps one hundred and fifty feet in diameter. It occurs mostly in small pieces, save at one place where there is an almost solid outcrop of perhaps twenty feet in diameter. The ore is of poor quality, being either cherty or porous, and full of sand.

INDIAN FORD BANK NO. 1 (M.).

N. ½, N. E. ¼, Sec. 24, T. 26 N., 7 E.

Here the ore is found on a low hill, not above fifty feet high. The ore lies on the southeastern slope of the hill in an oblong mass (or rather two masses with a vacant space between them), about three hundred feet long and one hundred at its widest. It reaches about half way down the hill. The most of this ore outcrop is in large pieces, but in the center they lie so closely connected as to seem an almost solid mass of broken ore. In quality it is porous and cherty, rather than sandy.

INDIAN FORD BANK NO. 2 (M.).

N. E. ¼, Sec. 23, T. 26 N., 7 E.

The principal mass of the limonite ore at this point lies on the southeast slope of a hill about one hundred and ten feet high. It shows at its thickest about ten feet below the top, although it is thinly scattered over the top and thick again at about the same level on the northwest. It reaches some thirty feet below the summit, extending down in a belt about eighty to one hundred feet wide. In its most promising outcrop it shows apparently solid but limited in extent, while the most of the ore is in large pieces. The quality of the ore is poor, being both cherty and sandy.

INDIAN FORD BANK NO. 3 (M.).

S. ½, N. W. ¼, Sec. 23, T. 26 N., 7 E.

The ore here occurs on the southeastern slope of a hill about thirty feet high. Near the top it shows an almost entirely coherent mass, seventy-five feet to one hundred feet long, and extends with this width down the slope, about one hun-

dred and fifty feet, in an outcrop of broken pieces, ranging from six inches to three feet in diameter. The ore is porous and quite free from chert, but is inclined to be sandy.

INDIAN FORD BANK NO. 4 (M.).

S. ½, N. W. ¼, Sec. 22, T. 26 N., 7 E.

This is a large deposit of ore, occurring on the northwestern slope of a hill about fifty feet high. Near the top, the ore lies in an apparently coherent mass, and below, it scatters, spreading over a large area. The ore is lean, soft and sandy.

MILLER BANK (M.).

N. W. ¼, N. E. ¼, Sec. 35, T. 26 N., 6 E.

The ore here lies upon the top of a hill, on the south side of Indian creek in two outcrops. These cap the highest points of the hill, but are separated by a shallow depression in which no ore is found, nor does it extend far down the slope. It is sandy and ocherous — the southern outcrop being little more than a ferruginous sandstone.

MISSOURI LUMBER AND MINING COMPANY LAND NO. 1 (L.).

Sec. 36, T. 25 N., 4 E.

The limonite at this locality makes quite an extensive surface showing, appearing at the foot of a mountain with a rather steep slope. It appears first at the bank of a branch, in a reef-like deposit making an area ten feet wide and fifteen feet long, where only huge solid masses of ore are seen. At short intervals for one hundred yards smaller, but otherwise similar, deposits are seen. Massive boulders are scattered all along within this area, which is about ten yards wide. The quality of the ore varies. Portions of it are hard and quite sandy, other portions contain small chert fragments and others are almost entirely free from insoluble material. Just east, along the same bank of this branch, sandstone is exposed in place. Above the ore, on the slope, pieces of chert and blocks of sandstone are seen. This locality is ten or twelve miles west of Poplar Bluff on the St. L., I. M. & S. Ry.

ST. FRANCIS BANK (M.).

S. ½, N. W. ¼, Sec. 24, T. 26 N., 7 E.

Limonite occurs here on a steep slope of a hill, about eighty feet high, which rises almost from the edge of the water, on the west side of the St. Francis river. The ore has been traced for a distance of five hundred and fifty feet along the hill. It lies scattered in immense boulders from the sixty-five foot level. At this height, for a distance of two hundred to three hundred feet, the ore shows a persistent outcrop, which seems in a number of places to be solid and is in position. The thickness of it could not be well ascertained. At the southern end of the hill the ore lies in greater abundance over a wider surface, and lower down on the hill, in broken pieces of greater or less size. Some two or three hundred yards to the southwest, on the bank of a small branch which

flows into the St. Francis river, is a large amount of ore lying scattered in large boulders, on both sides of the creek. The ore is only medium in quality, being porous and sandy with small chert admixtures at some places.

SHROUT'S BANK (M.).

N. E. ¼, N. E. ¼, Sec. 16, T. 27 N., 6 E.

The ore here lies in scattered lumps, for a distance of five hundred feet along the steep slope, and perhaps one hundred feet wide, while, at one place at the top of the hill, a solid outcrop is seen showing six or seven feet in thickness of very cherty and siliceous limonite. The outcrop of solid ore does not show for any great length. There are in it occasional seams of better ore running through the mass, but the best showed silica in coarse grains. The whole outcrop is extremely sandy, and the ore of the solid outcrop is both sandy and cherty.

In the N. E. ¼, of the S. E. ¼, of this same section, there is a smaller outcrop of ore in large and small pieces scattered over an area one hundred feet east and west, by one hundred and seventy-five feet north and south; at some places the mass seems to be solid. The ore is porous, semi-concretionary and quite cherty, while many of the cavities of the concretions are filled with sand.

SWATTLER BANK (M.).

N. E. ¼, N. W. ¼, Sec. 28, T. 26 N., 6 E.

The limonite, in a belt about seventy-five to one hundred feet wide, lies along the ridge and down the point to the bottom, a distance of five hundred feet, on a low hill. Down the slope it is in broken pieces, mostly of a large size; but higher up it lies in apparently a solid mass, which shows at one place ten feet thick. The solid outcrop is, however, of limited extent, and the great portion of the ore is broken. It is of medium quality, porous and sandy.

REPORTED LOCALITIES.

Mr. J. W. Clarkson reports the occurrence of limonite in the S. ½, N. W. ¼; N. W. ¼, N. W. ¼; and in the N. W. ¼, S. W. ¼, Sec. 16, T. 26 N., 7 E.

CAMDEN COUNTY.

FURNANCE BANK (S.).

Sec. 4, T. 39 N., 18 W.

Limonite is found here, lying on the irregular surface of the Third Magnesian limestone, which makes up the main body of the hill. The ore seems to form in some places a layer of irregular thickness on the limestone and to fill pockets and cavities in this rock. One of these cavities was found to be at least twelve feet deep. The openings show a considerable quantity of good limonite.

WHITE BANK (S.).

S. E. ¼, Sec. 7, T. 39 N., 18 W.

Limonite is found here in a bed, one to four feet thick. It occurs in the following section. Layers of yellow sand and variegated clays with more or less broken strata of sandstone; a layer of white chert one to three inches thick; white and green clay in thin and irregular layers, with sand and chert, one to three feet thick; dark red to brown, strongly ferruginous clay or loam six inches to two feet thick; limonite soft and earthy, enclosing irregular masses of hard, solid ore of more or less stalactitic structure; a layer of decomposed limestone from two to thirty inches thick and the regular Third Magnesian limestone.

CARTER COUNTY.

BROWN (J. C.) LAND NO. 1 (L.).

N. ½, Sec. 35, T. 27 N., 1 E.

Limonite is found here extending from the point of a spur of a hill down a rather steep slope, covering the greater portion of an area two hundred and seventy-five feet long and fifty feet wide.

The ore occurs in the form of fragments and rough masses, or boulders of massive ore. At the point of the spur, and at the margin of the deposit, the ore is quite cherty, elsewhere it is non-siliceous. These boulders contain small ocherous particles; but, on the whole, are quite compact. Thirty feet down the slope a shaft forty feet deep was put down in 1882. The section here was as follows: loose ore fragments on the surface and in the red clay; at a depth of six feet, one side of the shaft is a mass of hard chert two feet thick with rough masses of good ore imbedded in the clay, on the other three sides ore occurs in this manner to a depth of twenty feet from the surface. Below this depth to the bottom of the shaft, which is also in ore, the ore is in a more solid bed, occurring in larger masses with a less amount of clay, rendering blasting necessary. Other *more shallow* holes have been dug within this deposit and iron was invariably found beneath.

This locality is about three miles distant from the Current River railway and there is now a strong probability that a spur from Chilton will be laid in the valley at the foot of the hill. This if built will bring this deposit only about one hundred and fifty yards from railroad transportation.

BROWN (J. C.) LAND NO. 2 (L.).

W. ½, S. W. ¼, Sec. 13, extending into Secs. 14, 23 and 24, T. 26 N., 1 W.

The limonite in this locality covers an area nearly two hundred feet long and one hundred and thirty feet wide. It is located on the spur of a mountain, considerably below the summit. Two shafts, each fifteen feet in depth, have been sunk. They show a considerable body of ore. The ore is highly siliceous. The silica is principally in the form of drusy quartz and sandstone. The siliceous material could be separated from the ore by cobbing. The hills in

this vicinity show abundant traces of scattered, small deposits of ore; but one of these indicate an extensive one. This deposit is two or three miles from the C. R. Ry.

CARTER (A.) AND MISSOURI LUMBER AND MINING CO. LAND NO. 2 (L.)

Center of N. W. ¼, Sec. 13, T. 26 N., 1 E.

On the property of Mr. Alex. Carter and of the Missouri Lumber and Mining Company. Limonite occurs here on the foot of a gradual slope covering eight or ten square yards. The ore is found in irregularly shaped masses. Higher up the hill, on steeper slopes, and mingled with the masses of iron ore, fragments of chert and small blocks of hard sandstone occur. The majority of the ore masses are of fair quality, others are siliceous, silica occurring as small chips of chert. This locality is but little more than one mile from Chilton.

MISSOURI LUMBER AND MINING COMPANY LAND NO. 3 (L.).

S. ½, S. W. ¼, Sec. 12, T. 26 N., 1 E.

Limonite is found here on the foot of a spur covering an area about fifteen yards square. The ore occurs in the form of numerous rough masses. Some of these masses are but slightly siliceous, others are stronger and contain small chert fragments. Chert is found on the adjacent portions of his hill. This small deposit is about three-fourths of a mile from the Current River railway.

MORELAND BANK (L.).

N. E. ¼, N. E. ¼, Sec. 28, T. 2 N., 3 E.

Limonite is found here covering an area about sixty yards long and thirty yards wide. The ore occurs over a hill slope of moderate inclination in the form of large boulders and small pieces and in what may prove to be a ledge. The ore is somewhat siliceous, silica appearing both as fine grains of sand and as small chert fragments. Small masses of chert are on all sides of the exposed iron ore, but very little lies within the area. This deposit is about three miles distant from the St. L., C. G. & Ft. S. Ry.

REPORTED LOCALITIES.

Mr. F. Webb reports iron ore as occurring in S. E. ¼, Sec. 13, T. 26 N., 1 E., on the property of Mrs. Mary Kelley.

Mr. Alex. Carter reports iron as occurring in S. E. ¼, S. E. ¼, Sec. 12, T. 26 N., 1 E.; in S. W. ¼, S. W. ¼, Sec. 7, T. 26 N., 2 E., on the property of the Missouri Lumber and Mining Company; in E. ½, Sec. 17, T. 26 N., 2 E., on the land of Mr. Davis Smith; in E. ½, Sec. 2, T. 27 N., 2 E., on the property of Patrick O'Reilly, and in S. E. ¼, S. E. ¼, Sec. 31, 28 N., 2 W., on the property of Mr. M. Abbott.

associated rock. Limestone is exposed about two hundred yards away. This locality is about thirteen miles distant from the K. C., Ft. S. & M. Ry.

REPORTED LOCALITIES.

Mr. W. M. Briggs reports limonite as being found in the west side of Sec. 6, T. 26 N., 11 W.

Col. P. P. Dobozy reports limonite as occurring in Sec. 28, T. 25 N., 14 W.

Mr. D. S. Wood reports limonite as found in E. ½, Sec. 34, T. 27 N., 12 W.; in Sec. 11, T. 26 N., 12 W.; in Sec. 3, T. 26 N., 12 W.

FRANKLIN COUNTY.

BOWLEN BANK (S.).

N. W. ¼, Sec. 5, T. 41 N., 2 E.

Here there is the following succession of rocks, beginning with the lowest: solid and uniform mass of pure, hard, chocolate brown limonite, porous; then clayish limonite, with irregular masses of yellow ocher, soft and friable; red loam, with green and gray broken chert; then sandstone colored and impregnated with oxides of iron, in disturbed and broken layers; then dry soil with some chert.

IRON HILL (S.).

Sec. 17, T. 42 N., 1 E.

What is known as the Iron Hill deposit seems to consist of numerous smaller cracks and cavities on the surface of the Third Magnesian limestone, which cavities are in part or wholly filled with brown limonite and with yellow ocher. In the deepest of these cavities we find deposited a loose, coarse-grained and ferruginous, thinly stratified sandstone, which has afterwards been broken up again and partly destroyed. The point of the cavity is filled with white clay and with broken white chert. All the rest of the cavity is nearly filled with limonite, in irregular, botryoidal and stalactitic forms, mixed with yellow ocher and some chert. The lower part is mostly ocher; above are found pieces of heavy spar. The thickest and least porous forms of the limonite enclose sometimes a core of pyrites.

STANTON HILL BANK (S.).

S. W. ¼, N. E. ¼, Sec. 36, T. 41 N., 2 W.

Here there is a circular depression of about fifty feet diameter, in a dark colored sandstone which crops out all around, and toward the center grows very ferruginous, where it has almost the appearance of crystalline specular ore. The only pure ore found is a limonite.

WILDY'S (ISAAC) MINE (A. W.).[1]

S. W. ¼, S. W. ¼, Sec. 17, T. 42 N., 1 E.

Limonite is dug here from open pits, three to ten feet deep. A number of car loads have been shipped to St. Louis. This is said to contain 52 per cent or more of iron. A copy of analysis seen by the writer showed 0.15 per cent of phosphorus. The deposit is located immediately adjacent to the St. Louis & San Francisco Ry., on the north side, and about two miles east of Moselle. Another deposit is exposed in the railway cut, about two hundred yards east of Wildy's, which shows very plainly the relation of the ore to the magnesian limestones; it occurs in a chimney or cavity in these rocks. Blocks of limonite are found strewn over the surface of many other localities of this neighborhood.

HOWELL COUNTY.

GODSEY (D.) LAND (L.).

Stalactitic or pipe ore is found here in fragments of various sizes, scattered over an area of several square yards. The ore occurs on the slope of a hill the surface of which shows many blocks of sandstone and some chert. Here a shallow hole has been dug and some pieces with a sandy clay were taken out.

LAMONS MINE (N.).

A full description of this mine and the occurrence of the ore will be found in Chapter VII.

REPORTED LOCALITIES.

Capt. Jno. Halstead reports the occurrence of iron in lot 7, S. W. ¼, Sec. 7, T. 21 N., 10 W., known as the Smith, Tyree and Howard deposit.

IRON COUNTY.

REPORTED LOCALITIES (N.).

Mr. A. H. Eaton reports the occurrence of limonite in Sec. 34, T. 34 N., 1 W., and in Sec. 27, T. 35 N., 1 E.

MADISON COUNTY.

FORD BANK (S.).

T. 33 N., 7 E.

One-half mile from Cornwall station, on the Belmont Branch of the St. L., I. M. & S. Ry., is what is known as the Ford limonite bank. The ore-indica-

[1] From notes of Arthur Winslow, State Geologist.

tions on the surface extend about fifteen hundred feet along a low, flat hill, to a width of about five hundred feet. In the cut in which this bank was mined information as to the occurrence of the ore was obtained. The limestone underlying the ore is not visible save in single, large rounded masses of irregular shape. Above the limestone the ore lies. It is a limonite. It consists of irregularly mixed masses of yellow and reddish-brown, porous limonite, frequently in botryoidal and mammillary forms. The softer and harder ore occasionally passes into a pure yellow ocher. The best and hardest ore is in the upper part of the deposit. The ores are, in some places, clayish and contain seams of brown and red clay. The thickness of the ore is very variable and irregular; it is in places ten feet and less, and at other places reaches thirty feet. Above the ore is an irregular layer of reddish-brown clay, fine, pure, varies in thickness from six inches to fifteen feet and is rather uniform in color. Above this clay is a layer of broken chert two to three inches thick, and above this, one to five feet of soil, enclosing chert and surface-ore.

FOSTER BANK (M.).

N. E. ¼, Sec. 16, T. 33 N., 7 E.

Years ago three cuts were made in this quarter section. The upper cut was made near the end of a tramway constructed to carry the ore to the Belmont branch of the St. L., I. M. & S. Ry., about half a mile distant. This cut was eighty feet long running into the hill near the summit. Considerable ore was obtained but it was all found as broken pieces or boulders lying in the clay and chert. No solid mass was found. About two hundred and seventy-five yards north, by the side of the tramway, another small excavation was made and a better quality of ore, occurring as in the first cut, was found. At still another point, west of the last described, an excavation ten feet deep was made disclosing a mass of ore of irregular shape, the extent of which could not be seen. It was lying in clay mixed with yellow ocher and ferruginous chert. The ore itself was denser and very siliceous. No rock was visible near the ore, save the abundance of chert which was also within the ore area.

MATTHEW'S MOUNTAIN (S.).

Sec. 3, T. 32 N., 6 E.

Limonite occurs here in the form of large, rounded boulders and fragments The hill on which this ore is found is of porphyry. This rock mass is covered with a thick layer of porphyritic detritus, with large, sharp cornered pieces of porphyry and with these are mixed the limonite boulders. Near by some test pits were sunk to a depth of five or ten feet, in which boulders of ore were found mixed with the detritus. The prevalent rock in this locality is limestone, with cherty soil, but porphyry hills are abundant.

MORGAN COUNTY.

COUT'S BANK (S.).

Sec. 14, T. 40 N., 19 W.

Limonite lies here on the eastern slope of a hill, in a zone about thirty feet wide, extending one hundred and fifty feet down the hill-side. The ore is massive but frequently mixed with fine, broken chert. A large amount of broken chert is seen on the surface, but there is no bedded rock exposed.

PALM BANK (S.).

N. W. ¼, Sec. 12, T. 40 N., 19 W.

Limonite is found here in a ravine upon the western slope of the hill, near the base. It seems to occur in place and is about four feet thick. Around the outcrop, within a radius of thirty feet, is a large amount of surface-ore, which extends in smaller quantities to a distance of fifty or sixty feet up the slope. The soil is mixed with chert. No other rocks are visible.

WIGWAM BANK (S.).

Sec. 10, T. 40 N., 19 W.

Here limonite is found on the western slope of a cherty hill, the lower portion of which seems to consist of a sandy, magnesian limestone. The ore extends about one thousand feet along the slope and sixty feet vertically. Some sandstone is formed on the surface of the upper part of the hill, a short distance from the ore and apparently above it. The ore is very largely mixed with chert so much so as to form breccia in some places. There are, however, portions of it which are pure.

OREGON COUNTY.

BOYD (T. J.) LAND (L.).

N. W. ¼, N. W. ¼, Sec. 29, T. 22 N., 5 W.

Limonite is found here covering an area nearly two acres in extent, on a moderate slope. It first appears near the lowest portion of a spur and continues up the slope. On the surface here, ore was found in the form of boulders and smaller fragments. This surface ore was shipped five or six years ago. Two excavations have been made a few yards apart near the center of the area. One of these is about ten feet in length, six feet in width and nine feet deep; the other is not so deep, but is longer. From both a considerable amount of ore was removed. The ore in these cuts was found occurring with red clay. It is of a fair quality. It contains soft ocherous particles but is only very slightly siliceous. There are fragments of white chert on this range of hills and, here and there, are found traces of scattered ore. This locality is located less than two miles distant from the K. C., Ft. S. & M. Ry.

HAINS (J. N.) BANK (N.).

Sec. 34, T. 24 N., 4 W.

For description of this bank, see Chapter VII.

MT. NEBO ORE (N.).

Sec. 8, T. 23 N., 3 W.

For a description of the two occurrences of limonite on Mt. Nebo, see Chapter VII.

MURRAY LAND (L.).

N. E. ¼, S. W. ¼, Sec 33, T. 22 N., 5 W.

Limonite is found here. There is but little surface ore shown and much chert. A shaft was sunk, by Mr. T. J. Boyd, to a depth of eighteen feet. The upper ten feet is made up of a dark red clay, portions of which is cherty and to this depth but few pieces of ore were discovered. The lower eight feet is principally iron ore intermixed with a small amount of red clay. Mr. Boyd reports the bottom of the shaft as being an almost solid bed of iron ore. Many of the masses of ore are coated with small and large crystals of limonite, pseudomorphous after pyrite, and the surfaces of some of the masses are ribbed with veins of ore, in relief, which once filled crevices in the adjacent wall-rock. The ore is of a good quality. Some yellow ocherous matter occurs with the ore. This deposit is situated less than one mile from the K. C., Ft. S. & M. Ry. at Thayer.

OLD (J. B.) BANK (N.).

Four miles northwest of Thomasville.

For a description of this bank, see Chapter VII.

RAGAN (T. B.) LAND (L.).

N. E. ¼, N. W. ¼, Sec. 33, T. 22 N., 5 W.

Here, on the slope and cap of a spur, limonite is found covering an area seventy yards long and thirty yards wide. The ore occurs in the form of small and large masses and the entire area is almost completely covered with such. Chert fragments are found on adjacent sections of the hill. It is not a siliceous ore, but these masses contain softer, lighter-colored ocherous particles. This deposit is about one mile from the K. C., Ft. S. & M. Ry.

REPORTED LOCALITIES.

Mr. T. J. Boyd, of Thayer, reports the occurrence of limonite in Sec. 17, T. 23 N., 3 W., and in Sec. 2, T. 22 N., 3 W.

OZARK COUNTY.

COBB (H. C.) LAND (L.).

N. W. ¼, Sec. 23, T. 23 N, 12 W.

This deposit of limonite is found on the slope of a low hill and in a small ravine. The ore is in the form of rough boulder-like masses and fragments. Such ore-masses are found covering an area nearly an acre in extent. Within this area and on adjoining portions of this slope, chert fragments occur. The general quality of the ore is good, though a few of the fragments show some chert particles. This is about thirty miles distant from the Gulf Ry.

COLLINS (LOWELL) LAND (L.).

Sec. 30, T. 24 N., 11 W.

Limonite occurs here on the slope of a hill in the form of a few scattered boulders on the surface. Within this area a hole two feet deep was dug, from which lumps of ore were removed, and at the bottom an almost solid deposit was exposed. The ore in the pit is of the species limonite and turgite. Some chert fragments are disseminated with the surface ore. This deposit is about the same distance as the last from the same railroad.

JAMES (WM.) LAND (L.).

Secs. 27 and 34, T. 24 N., 11 W.

Limonite occurs in several localities in these sections, extending over three hundred and twenty acres. The extent of the individual deposits varies from one-fourth of an acre to more than an acre. These deposits are usually on the gradual slopes though some do occur on steeper slopes. At one place scattered fragments are seen which extend from the gradual slope at the base nearly to the point of the spur. The ore is non-siliceous and the fragments are mingled with loose chert. This locality is about twenty-five miles from West Plains.

LAMB (JOHN) LAND (L.).

Sec. 25, T. 23 N., 12 W.

Limonite is found here on a moderate slope, covering an area one hundred and twenty-five yards long and thirty yards wide. The upper limit is quite near the summit of the hill. The portion of the area nearest the summit of the hill is made up almost wholly of small boulders and fragments. The remaining portions contain chert fragments and blocks mingled with small pieces of ore. The quality of the ore is fair, most of the ore being non-siliceous or nearly so. This locality is nearly thirty miles from the K. C., Ft. S. & M. Ry.

LUNA (RICHARD) LAND (L.).

Sec. 21, T. 24 N., 12 W.

A limonite bank occurs here on a very gradual slope, in the form of scattered fragments and boulders covering an acre or more. It is a fair quality of ore.

These boulders of ore are mingled with scattered fragments and large masses of chert. This locality is about twenty-five miles distant from the K. C., Ft. S. & M. Ry.

MAHAN LAND (L.).

N. side of Sec. 1, T. 23 N., 12 W., and S. side Sec. 36, T. 24 N., 12 W.

Limonite is found here in three localities, each area being about thirty yards square. The first is near the summit of the hill. Here the ore boulders and fragments bear grains of sand and small particles or spalls of chert, mingled with them. About seventy-five yards westward, on a gentle slope, is another similar deposit; and northward, about one hundred yards, very small fragments of good, dark brown limonite are thickly strewn over the surface. This area also bears fragments of chert. This deposit extends over a low crest and down a moderate slope. This ore is about twenty-five miles from the K. C., Ft. S. & M. Ry.

MARTIN (ANDREW) LAND (L.).

Sec. 1, T. 23 N., 12 W.

Here, near the foot of a rather steep slope bearing much sharp chert gravel, large fragments of chert and scattered small blocks of sandstone, is found an area, ten yards square, covered with limonite boulders and fragments. The greater portion of the ore is non-siliceous, though some pieces are seen to contain small particles of chert. Bedded limestone is outcropping just beneath the area. About one-third of a mile from this deposit, on the northern point of a spur leading off from the same hill, is an area, about three fourths an acre in extent, containing rough masses and fragments of good, non-siliceous limonite. Within this area are found a few fragments of chert and "cotton rock." Again, about one hundred yards westward, on a low, rather flat slope, are found masses of limonite scattered over several square yards. At this locality limestone is again exposed. These deposits are about twenty-five miles distant from the K. C., Ft. S. & M. Ry.

MATTNEY (JAMES) LAND (L.).

Sec. 6, T. 23 N., 11 W.

Limonite is found here on the slope of the hill near the foot, covering, perhaps, one-fourth of an acre. It occurs in the form of boulders and fragments, mingled with chert. It is a good quality of ore, being non-siliceous and firm. Much chert is found on adjacent portions of the hill. This locality is about twenty-four miles from the K. C., Ft. S. & M. Ry.

MORE LAND (L.).

Sec. 35, T. 23 N., 11 W.

Limonite is found here on the gradual slope at the base of a hill, and extending up the steeper slope, about two hundred yards west of a branch of Big North Fork of White river. The boulders and fragments are strewn over about one acre. Some of these boulders occur in masses forming a reef-like deposit; others are smaller and more scattered. Large and small white chert

boulders occur mingled with and above the ore boulders. This locality is about thirty-five miles distant from the K. C., Ft. S. & M. Ry.

OWENS (JOSEPH) LAND (L.).

Sec. 6, T. 23 N., 11 W.

Here, on the southern slope of a broad hill, limonite occurs in fragments and small boulders, covering an area an acre or more in extent. It is non-siliceous and heavy. Some pieces of chert are found within this area and on the adjacent portions of the hill. This locality is about thirty-four miles distant from the K. C., Ft. S. & M. R. R.

PETECOCK LAND (L.).

N. W. ¼, Sec. 36, T. 24 N., 12 W.

Limonite occurs here in two localities on the point of one and near the point of another short hill. These localities are only a few yards across, about one-eighth of a mile apart and separated only by a slight depression. It is reported that fragments of ore could be seen in the now cultivated field between the two areas. The ore in the eastern area is somewhat siliceous, more so than that in the western area. These localities are about twenty-five miles from the K. C., Ft. S. & M. Ry.

PRATT (WALLACE) LAND (L.).

Sec. 17, T. 24 N., 11 W.

Only a few fragments and boulders of limonite are found here on a gradual hill slope. Some excavating has been done and a deposit of iron was met with at a depth of from four to nine feet under the surface. The surface material, such as clay, chert and soil, has been removed from over the ore and has exposed the deposit, which shows an almost solid body for ten yards or more. No work has been done to prove the thickness of the deposit, but several slab of ore which were taken out show the thicknesses of the individual layers to range from three to six inches. Other, more massive pieces were also obtained. The general mass shows little or no silica and, on the whole, the ore is of very fair quality. This deposit is about twenty-six miles from the K. C., Ft. S. & M. Ry.

SOUTH MISSOURI LAND COMPANY LAND NO. 1 (L.).

Sec. [illegible], T. [illegible] N., [illegible] W.

Here we have but slight surface indications of iron ore, in the form of small fragments scattered over the ground. Two shafts seven feet deep were sunk about one-half of a mile apart on a rather flat top of a ridge, next to Big North Fork of White River.

In the easternmost shaft, where only chert chips and soil might be seen on the surface, small boulders of good ore were met with from near the top to the bottom. This shaft was near the brink of the hill. At the other shaft, sixteen inches of soil and clay were passed through, then clay was penetrated containing ore boulders such as were found in the former shaft. The ore is non-siliceous. These shafts are about one-fourth of a mile from a spur, whose bluff-

like side next to the Big North Fork of the White river, shows stratified limestone and sandstone. This locality is thirty miles or so from the K. C., Ft. S. & M. Ry.

SOUTH MISSOURI LAND COMPANY LAND NO. 2 (L.).

Sec. 34, T. 24 N., 11 W.

Limonite is shown here, on the surface, in a few small fragments. Four holes have been dug. One is on the point of the hill, another about one hundred yards northwards on the slope, another two hundred yards further northward and one more about the same distance in the same direction. The depths of these holes range from four to ten feet and, in each, a solid body of limonite was struck just beneath a deposit of rather fair, broken ore, cementing angular fragments of hard and decomposed chert. Underneath this deposit the ore proves to be more free from insoluble material. Scattered chert fragments are seen on the surface. This deposit is about thirty-miles from the K. C., Ft. S. & M. Ry.

TANNER LAND (L.).

Sec. 34, T. 24 N., 12 W.

Limonite occurs here in widely scattered fragments and boulders on a steep slope covering an area seventy-five yards long and about ten yards wide. The quality of the ore is very fair. Much chert, in fragments and in larger rough masses, is found within the area and over the hill. This locality is about twenty eight miles distant from the K. C., Ft. S. & M. Ry.

WARREN (JUDGE PINKNEY) LAND (L.).

Sec. 36, T. 24 N., 12 W.

Limonite is found here again in the form of large and small fragments in scattered deposits over four or five acres, usually on the slope. The quality of the ore is good. The fragments of ore are mingled with fragments of white chert. The surface exposure in one of the deposit within this large area is more than one acre in extent. This deposit is between thirty and thirty-five miles distant from the K. C., Ft. S. & M. Ry.

WELLS LAND (L.).

Sec. 5, T. 23 N., 11 W.

Massive limonite is found here on a cherty slope in the shape of large boulders and chips, covering an area twenty yards long and fifteen yards wide. The ore is hard and quite or nearly as pure. This locality is about thirty-three miles from the K. C., Ft. S. & M. Ry.

REPORTED LOCALITIES.

Col. P. P. Dobozy, of Dora, Mo., reports iron ore as occurring in the following localities: Sec. 2, T. 23 N., 14 W.; Secs. 3, 4 and 7, T. 23 N., 13 W.; Secs. 25 and 35, T. 24 N., 13 W.; Secs. 12, 32, 33, and 35, T. 24 N., 11 W.; N. ½, Sec. 8, T. 22 N., 12 W.; Sec. 2, T. 22 N., 13 W.; Secs. 16 and 17, T. 22 N., 11 W., and several deposits in T. 23 N., 14 W., sections unknown.

REYNOLDS COUNTY.

LESTERVILLE BANK (L.).

N. E. ¼, Sec. 8, T. 32 N., 2 W.

About one mile north of Lesterville, on the sharp crest and moderately steep slope of the point of a hill, boulders and irregularly shaped masses of limonite occur over an area of, perhaps, one acre in extent. These masses of ore are quite numerous and are found with fragments of chert. It occurs in the form of pipe-ore and possesses a very good quality.

REPORTED LOCALITY.

Judge A. J. Parks reports the occurrence of a deposit of pipe-ore in the N. W. ¼, Sec. 5, T. 32 N., 2 E.

RIPLEY COUNTY.

AGRICULTURAL COLLEGE LAND NO. 2 (L.).

N. side of Sec. 19, T. 23 N., 3 E.

Limonite here covers a small area near the higher position of a flat-topped hill. It occurs in the form of fragments and also cementing small pieces of white chert; it contains fine grains of silica. This deposit is about six miles from Doniphan.

[illegible] LAND [illegible]

[illegible]

[illegible] at the summit of the hill [illegible] yards wide. This ore contains [illegible] This property is about [illegible] a similar deposit in the N. [illegible]

[illegible]

[illegible]

[illegible] near the summit of [illegible] This [illegible] exposed at the base [illegible] from the [illegible]

CURRENT RIVER LAND (L.).

N. ½, Sec. 24, T. 22 N., 2 E.

Limonite covers here an area about sixty yards long and thirty yards wide. The ore is in the form of huge boulders and probably occurs in ledges. It is fair in quality. Some of the ore cements small chert chips. Small fragments of loose chert are found within the area and on adjacent portions of the hill, but no bedded rock. This deposit is about five miles from the Doniphan Branch Ry.

DALTON (LEVI C.) LAND (L.).

Sec. 9, T. 22 N., 1 E.

Iron ore occurs here near the foot of a hill of moderate slope. Only a few small pieces are to be seen on the surface, but recently Judge Dalton has sunk a shaft six feet deep and in so doing, has taken out many fragments of ore. This ore is in the form of masses an inch or so thick, somewhat botryoidal and frequently several such masses are cemented together. It is non-siliceous, or nearly so, and occurs both as limonite and as dark red fibrous turgite. These masses are disseminated through reddish yellow clay. This locality is ten miles from the Doniphan Branch of the I. M. Ry.

EATON (Z. A.) LAND (L.).

Sec. 25, T. 23 N., 3 E.

Limonite occurs here in boulders scattered over an area about fifty yards square, on the top of a hill. These boulders are either somewhat spongy, or porous, or are hard and of a light brown color. Most of the boulders are but slightly siliceous, others contain small fragments of chert. With the ore there is much soil and but little chert and no bedded rock. This deposit is only about one mile from the Doniphan Branch of the I. M. Ry.

GRAY (MRS. LYDIA) LAND (L.).

Sec. 31, T. 23 N., 3 E.

Limonite is found here over an area about twenty yards square. The ore is in rough masses and is found capping the spur of a hill. It is very siliceous, silica occurring as grains of sand. Chert chips and boulders are found on other portions of this hill. About one-third of a mile east of this deposit, on the property of Mr. H. R. Walland, is another deposit of similar ore. Scattered masses appear over about as large an area as the last. The associated rock and the mode of occurrence of the ore are also similar.

GOVERNMENT LAND NO. 2 (L.).

Sec. 16, T. 22 N., 1 E.

Limonite is found in fragments on the flat extension of a high hill which occurs at this place. The ore exists as pipe, or stalactitic, massive and pseudomorphous after pyrites. Each variety is non-siliceous. Only scattered

fragments of ore mingled with much chert are seen on the surface around the ore area, with limestone exposed just a few feet lower on the hill.

GOVERNMENT LAND NO. 3 (L.).

Sec. 7, T. 22 N., 2 E.

Limonite is found here covering an area about one hundred and ten yards long and from fifteen to forty yards wide. It occurs on a long, narrow, low spur. The lower half of this area is composed almost entirely of this ore, the upper half contains some fragments of chert. Higher on the hill chert and no ore is found. The ore occurs in the form of irregularly shaped masses and fragments of stalactitic and massive types. It is of a very good quality and only a few masses contain small fragments of chert. On another spur of this hill, and about one hundred and fifty yards northwest of the last deposit, there is an area fifteen yards square which is probably an extension of the last, as the ore is similar and occurs similarly. This deposit is on the land of Mr. Joseph Jaco. Again two hundred yards west, near the base of yet another spur from this same hill, also on Mr. Jaco's land, several large boulders and blocks of semi-massive and stalactitic limonite are found, covering perhaps twenty yards square. There is little doubt but that this last deposit belongs to or is connected with the two deposits just described. Across the branch from these, small fragments of good brown ore mixed with much chert are found. The slopes of the hill in each of these cases are very gradual.

GOVERNMENT LAND NO. 4 (L.).

Sec. 1, T. 23 N., 1 W.

Limonite occurs in the form of fragments scattered over several square yards near the summit of a hill. The surface fragments are mingled with chert. A shallow hole has been dug and many large and small pieces of ore, stalactitic in form, and of good quality were taken out. Limestone is exposed at a divide a short distance westward from the ore deposit. This locality is about eighteen miles from Doniphan.

HERR (C. B.) LAND (L.).

N. ½, Sec. 24, T. 22 N., 2 E.

Limonite is found here in scattered boulders over a number of acres. A few boulders and small fragments of chert are found within this area but no bedded rock is exposed. This locality is five miles distant from the Doniphan Branch Ry. The summits of the hills in this neighborhood are broad and in many localities numerous pebbles are found mingled with large chert fragments.

KING (E. M.) LAND (L.).

S. W. ¼, Sec. 24, T. 22 N., 2 E.

Limonite occurs in several localities covering small areas, on this hill. It is found in irregular masses and small fragments. It is somewhat siliceous,

containing a low percentage of silica, both as grains of sand and as short chips. Pebbles of sandstone and chert with some chert fragments are found on the hill. This locality is nearly six miles from the Doniphan Branch Ry.

MABREY (T. W.) LAND NO. 1 (L.).

N. W. ¼, Sec. 23, T. 23 N., 23 E.

Limonite shows here on the surface over an area of about eighty yards long and ten yards wide. The ore occurs, in the form of a reef-like deposit, in three localities, on the lower portion of a gradual slope, and in the form of boulders and fragments scattered over the whole area. It is only slightly siliceous, containing scattered particles of chert and grains of sand. Pebbles of sandstone and chert, chips of chert and blocks of sandstone are found on the same slope but no bedded rock is to be seen. This locality is about two miles distant from the Doniphan Branch Ry.

MABREY (T. W.) LAND NO. 2 (L.).

Sec. 13, T. 23 N., 2 E.

Limonite is here found covering portions of an area about thirty yards long and sixty yards wide. The ore occurs in the form of small boulders and fragments on the slope of a hill, and is associated with loose angular chert and large and small pebbles and small boulders of sandstone and chert. This locality is about one mile from the Doniphan Branch Ry.

MISSISSIPPI COUNTY LAND (L.).

S. E. ¼, S. E. ¼, Sec. 13, T. 22 N., 2 E.

Limonite occupies here two or three small areas on the gradual slope of a hill. The ore occurs in the form of large boulders and fragments and, although none of individual acres are large, the mode of occurrence would indicate a ledge or body of ore under the surface. It is a siliceous ore, silica occurring in the form of grains of sand. This deposit is located about four miles from the Doniphan Branch Ry.

MISSOURI LUMBER AND MINING COMPANY LAND NO. 4 (L.).

N. ½, Sec. 19, T. 25 N., 3 E.

Limonite covers here the greater portion of four or five acres, besides occurring as isolated boulders on different portions of the hill. The ore is in the form of rough masses extending along a steep slope from the top of a hill to the waters of the North Fork of Little Black river. Portions of the surface ore are quite siliceous, containing grains of sand and particles of chert, besides being porous. Some chert masses lie on the surface adjacent to the ore deposit. This deposit is about four miles from Grandin, on the C. R. Ry.

ODOM (MRS.) LAND AND THE MISSOURI LUMBER AND MINING COMPANY LAND NO. 5 (L.).

Sec. 31, T. 25 N., 2 E.

Here, scattered deposits of limonite occur over twenty acres. The mode of occurrence and the character of the ore varies to a certain degree in the different localities. At one place, on a gradual slope, we have light-brown, hard limonite fragments and small rough masses of the same with but little rock of any kind. This ore is quite siliceous. At another locality, on the top of this hill, and about one hundred yards from the first deposit, huge masses and fragments of ore have been exposed and appear to be parts of a more or less continuous reef-like mass. Within this area, which is quite large, nothing but ore may be seen. On the slope, about forty yards across a ravine, there is another, smaller but otherwise similar, deposit. These two heavy deposits, together with the surface fragments surrounding them, cover at least an acre. The ore is not heavy nor firm and contains a considerable percentage of silica, both as chert fragments and as grains of sand. This locality is about five miles distant from Grandin, the terminus of the Current River Ry.

PONDER (A. J.) LAND (L.).

Sec. 26, T. 23 N., 2 E.

Limonite occurs here on different portions of the hill. The principal area is near the foot, at the roadside. Here several large, massive and stalactitic ore boulders are exposed. The quality of the greater portion of the ore is good but particles of chert are contained in some of the boulders. This is only about two hundred yards from the Doniphan depot.

PONDER (D. K.) LAND (L.).

S. E. ¼, Sec. [illegible], T. [illegible] N., 2 E.

Limonite is found here covering an area of from twenty to thirty square yards. The ore is stalactitic in form, and the deposit forms a slight rise on the slope. The ore is non-siliceous and is in the form of large and small masses. This locality is only a few hundred yards from the Doniphan Branch Ry.

RIPLEY COUNTY LAND (L.).

Sec. [illegible], T. [illegible] N., [illegible] E.

Limonite is found here covering an area about thirty yards long and ten yards wide. The ore is in the form of rough boulders which make up the surface of the [illegible] portion of the top of the high hill. It is quite siliceous, silica occurring principally in the form of grains of sand. Years ago digging was done within this area but none of the ore was ever utilized. Some chert fragments are found over the entire hill and pebbles are seen on the northern slope and [illegible] near the base of the hill. This deposit is [illegible] miles from [illegible].

RANKEN (THOS. JR.), LAND (L.).

Sec. 35, T. 23 N., 1 W.

Here limonite occurs in the form of fragments and blocks over the surface of an area about forty yards long and twenty yards wide, on a rather steep slope. Within this area nothing but iron ore is found. It is a siliceous ore, silica occurring as grains of sand. Surrounding the ore area fragments of chert may be found, and in the ravine at the foot of the hill, limestone is found in place. This deposit is about nineteen miles from Doniphan.

STEPHENS (W. W.) LAND (L.).

W. ½, Sec. 19, T. 22 N., 1 E.

Limonite is found here covering an area about twenty yards long and forty yards wide and making up the point of a spur of a chert hill. It is not a heavy ore and is somewhat siliceous, silica occurring as grains of sand. Chert fragments are found on the hill adjoining the deposit of ore. This locality is about fourteen miles from the Doniphan Branch Ry.

STOOPS (P.) LAND (L.).

Sec. 14, T. 22 N., 1 E.

Here scattered fragments of good massive limonite are found with much chert on a high hill. At two or three places these fragments are quite numerous.

TOWELL (I. M.) LAND (L.).

Sec. 19, T. 22 N., 1 E.

Limonite is found here covering an area about thirty yards long and ten yards wide. It occurs as numerous rough masses on the steep slope at the foot of a high hill. The ore is quite siliceous, silica occurring both as fine grains of sand and small fragments of white chert. Other loose masses of similar ore are found about one hundred yards northeast and across the creek from this deposit. This area is only about fifteen yards square. Much surface chert gravel is associated with these deposits but no bedded rock is observed. This locality is about thirteen miles from Doniphan.

WILLIAMS (J. T.) LAND (L.).

Sec. 10, T. 22 N., 1 E.

Limonite occurs here on a gradual slope in the form of boulders of massive and pipe-ore. A litlle digging has been done here exposing one boulder about three feet in diameter and a few small pieces. The pipe-ore is of a good quality, but the massive portion is slightly cherty. Only a few blocks and fragments of iron can be seen. These are mingled with much chert and small blocks of limestone. This locality is, perhaps, nine miles distant from Doniphan.

WILSON (ROBERT) LAND (L.).

N. W. ¼, Sec. 18, T. 22 N., 3 E.

Limonite is found here covering three localities. The most southern area is about forty yards long and sixty yards wide. The other two deposits occupy about one-third of an area and are from one hundred and fifty to three hundred yards apart. The boulders are slightly porous but the per cent. of insoluble material runs rather high, silica occurring in the form of grains of sand. Pebbles of chert and sandstone and angular chert fragments are found over the entire area occupied by the three deposits. These localities are about six miles distant from the Doniphan Branch Ry.

REI [illegible] 'ALITIES.

Mr. Lyndsay Dudley reports [illegible] e of limonite in the S. ½, S. W. ¼, Sec. 12; N. E. ¼, Sec. 24, S.W. ¼, [illegible] t 1, N. W. ¼, Sec. 1, all of T. 22 N., 2 E. Hon. T. W. Mabrey re[illegible] rence of limonite in the E. ½ and N. W. ¼, Sec. 28, T. 24 N., 2 E. [illegible] Tompson and I. Hilliard report the occurrence of limonite in N. W. [illegible] T. 24 N., 2 E., and in the N. E. ¼, Sec. 18, and E. ½, Sec. 19, T. [illegible] E. Mr. I. W. Towell reports the occurrence of limonite in Sec. 2[illegible], 1 E.

ST. [illegible] OUNTY.

COPPER [illegible] K (S.).

Sec. 27, T. 39 N., 24 W.

This bank of limonite is upon the northwestern slope of a hill into which a shaft has been sunk to a depth of seventy-two feet. The shaft is in whitish limestone and follows a crevice which is filled with soft, earthy limonite. At the mouth of the shaft, stratified ore appears several feet in thickness, and above this an outcrop of ferruginous sandstone.

GREENWELL BANK (S.).

Sec. 15, T. 39 N., 25 W.

The ore occurs scattered over an area seventy feet long and forty feet wide on the slope of a low, flat hill. This hill is covered with chert and large, boulders of crystalline, gray limestone; part of the ore is hard and solid, and part is argillaceous.

SHELDON BANK (S.).

Sec. 8, T. 38 N., 24 W.

Limonite is found here in the form of boulders and fragments. On the lower part of the slope the ore is solid limonite, somewhat argillaceous and ochery and inclined to stalactitic forms. Higher up the hill it becomes more sandy.

SHANNON COUNTY.

CHILTON (W. S.) LAND (L.).

N. E. ¼, N. W. ¼, Sec. 27, T. 29 N., 4 W.

Massive limonite is found here on a low spur from a limestone mountain. It occurs on the northwestern slope and about the middle of the point of the spur, in the form of huge and small fragments. This area of surface ore is fifty yards long and thirty yards wide and within this area little else than iron ore can be seen.

In the northwestern margin of the deposit, a shaft of seven feet deep has been sunk, going through about six inches of soil; on the southeast side at a depth of one foot a solid vein-like deposit of limonite occurs, which curves downward and towards the northwest, at an angle of about sixty degrees. This vein is from four to ten inches thick and is of a good quality of massive limonite. The remaining portions of the shaft walls are weathered, stratified limestone. Some of the surface boulders are four or five feet in diameter but are filled with cavities. On the southern slope, about thirty yards from the surface ore, a shaft ten feet deep was sunk through limestone containing crystalline calcite masses disseminated through the strata. This deposit is about thirteen miles from the C. R. Ry.

CUTLER (W. P.) LAND (L.).

N. E. ¼, S. W. ¼, Sec. 33, T. 27 N., 5 W.

Here there is about an acre of land over which are found scattered, rough masses, or boulders of limonite. It is a light spongy variety, slightly siliceous, bearing fine grains of sand. There lies but very little surface rock near. The ore is on the rolling top of a chert range. This deposit is located about two miles distant from Birch Tree, on the C. R. Ry.

DEAN (J. H.) LAND (L.).

S. ½, Lot 2, N. W. ¼, Sec. 30, T. 28 N., 3 W.

Here, near the highest part of a mountain, there is but a small surface showing of ore; but a shallow pit has been dug and pieces of good limonite taken out. Mr. Vanausdall says solid ore was struck at the bottom of the hole. The ore is of a good quality. It occurs in light yellowish-gray, sandy clay. The associated rock is chert.

EMBREE LAND (L.).

N. W. ¼, N. W. ¼, Sec. 12, T. 28 N., 4 W.

Limonite is found here covering only a small area, at the lower extremity of a long flat point. It is a good ore and occurs massive and pseudomorphous.

FISHER (JOSEPH) LAND (L.).

S. W. ¼, Sec. 14, T. 26 N., 5 W.

Limonite is found here covering the crest of a spur of a broad hill in what is known as the pine-flat. The principal deposit is about one hundred yards long and twenty yards wide. There is a large amount of surface ore in the form of huge boulders and large and small fragments. The ore is somewhat siliceous, bearing silica in the form of minute grains of sand and now and then particles of drusy quartz. Just across a small ravine from this exposure is a small outcrop of a similar ore occurring in a similar manner. No rock is found within the areas described and but few scattered chert fragments are seen anywhere in this vicinity. This local[illegible] six miles distant from the Current River Ry.

GOVE[illegible] NO. 5 (L.).

S. E. ¼, N. E. ¼, [illegible] N. E. ¼, Sec. 24, T. 28 N., 4 W.

Stalactitic limonite is [illegible] localities on and near the summits of hills which are thickly cove[illegible] ents of chert. But little ore is on the surface, yet, at each locali[illegible] digging has been done and small and large masses of pipe ore [illegible] d. It is a good ore, some parts of it are pseudomorph after py[illegible]

MUNS[illegible] LAND (L.).

N. E. ¼ [illegible] T. 27 N., 3 W.

About an acre of land here [illegible] with iron ore. It occurs in the form of small and large fragments, on [illegible] e slope, near the summit of a mountain. Some portions of the ore are comparatively free from silica, other portions contain both chert fragments and grains of sand. The ore is somewhat porous and spongy. Small pieces of white chert and a few sandstone blocks are mingled with the fragments of ore, and about two hundred yards distant a sandstone bed is found. This is the nearest exposed bedded rock. This deposit is situated next to Sycamore branch of Pike creek, about two miles from the C. R. Ry.

TRIPP (G. W.) LAND (L.).

N. E. ¼, S. E. ¼, Sec. 31, T. 29 N., 3 W.

Limonite is found here along the steep southern slope of a limestone hill, with much exposed limestone appearing in places, about fifty feet lower than the summit. The ore occurs in pieces weighing from a few ounces to fifty pounds as pseudomorphs and also as stalactitic and massive ore. It is of a good quality and bears no visible impurities.

REPORTED LOCALITIES.

Mr. J. B. Reaser reports a small deposit of ore, occurring in S. W. ¼, Sec. 14, T. 26 N., 5 W., about two hundred yards to the southeast, and another larger one near the center of Section 23, of the same township and range.

Mr. W. S. Chilton reports pipe and pseudomorphous ore as occurring in two

localities in S. E. ¼, Sec. 15, T. 29 N., 4 W., on the property of Messrs. Carson and James. Messrs. Shuck and Munsell report iron as occurring in Sec. 16, T. 31 N., 6 W., on the property of Gov. A. J. Seay. Mr. L. L. Munsell reports the occurrence of limonite in the following localities: N. W. ¼, Sec. 21, T. 31 N., 4 W., on the property of the Midland Blast Furnace Company; in N. ½, N. E. ¼, Sec. 17, T. 28 N., 3 W., and S. W. ¼, N. E. ¼, Sec. 22, T. 28 N., 3 W., on the property of Mr. L. L. Munsell; in N. E. ¼, S. W. ¼, Sec. 17, T. 28 N., 3 W., a small deposit; in the S. W. ¼, N. E. ¼, Sec. 6, T. 28 N., 3 W., on the property of Mr. J. N. Deweese; in S. E. ¼, N. W. ¼, Sec. 13, T. 31 N., 6 W., on the land of the Missouri Furnace Company; in N. ½, Sec. 22, T. 31 N., 5 W., and in S. ½, Sec. 34, T. 31 N., 4 W., both owned by Messrs. Organ and Sweiney; in N. E. ¼, Sec. 8, T. 31 N., 3 W., in N. W. ¼, Sec. 9, T. 31 N., and in N. ½, S. W. ¼, Sec. 10, T. 26 N., 6 W., on the property of Mr. C. T. Biser; in S. ½, Sec. 15, T. 31 N., 3 W., on the property of Mr. L. B. Woodside; in N. W. ¼, Sec. 21, T. 31 N., 4 W., on the property of the Midland Blast Furnace Company; in the S. ½, Sec. 4, T. 27 N., 4 W., on the land of South Missouri Land Company; in N. W. ¼, S. W. ¼, Sec. 28, T. 27 N., 4, W., on land of Mr. Livsey; in S. ½, N. W. ¼, and N. ½, S. W. ¼, Sec. 34, T. 27 N., 4 W., on land of the Ozark Lumber Company; in S. W. ¼, N. E. ¼, Sec. 27, T. 27 N., 5 W., on the property of Mr. S. H. Knight; in N. E. ¼, Sec. 11, T. 26 N., 5 W., a small deposit, on the property of Mr. R. W. Phennighausen; in S. W. ¼, S. W. ¼, Sec. 19, T. 27 N., 5 W., and S. E. ¼, S. E. ¼, Sec. 24, T. 27 N., 6 W., both on government land. Mr. Raymond reports the occurrence of iron ore at the S. W. corner of Sec. 15, T. 27 N., 5 W., on the property of Mr. Wm. Thomas, and in N. ½, Sec. 28, T. 27 N., 5 W., on the property of Mr. D. Butler.

STODDARD COUNTY.

BURGE (WILLIAM) LAND (L.).

Sec. 17, T. 27 N., 9 E.

Here, on a gradually sloping crest of a long hill spur, sandy massive limonite is found. There are two small deposits a few hundred feet apart. The ore is in the form of loose, rough masses and of larger masses partially imbedded in the soil. Higher up the spur and on the point of the hill fragments and blocks of much more siliceous ore are found. This ore, belonging to Mr. Burge, is about one mile distant from the St. L., C G. & Ft. S. Ry.

GOFORTH (MRS. R. A.) LAND (L.).

N. W. ¼, Sec. 2, T. 26 N., 8 E.

Massive limonite in the form of boulders is found here on a gradual slope of a low hill, covering an area about twenty yards square. There is no associated rock. The soil is quite dark. The ore is but slightly siliceous, this small amount of silica occurring in the form of grains of sand. This deposit is about one mile from the St. L., C. G. & Ft. S. Ry.

HALL (H. E.) LAND (L.).

W. ½, Sec. 3, T. 26 N., 8 E.

Here on the property of H. E. Hall, W. I. Smith and John King, massive limonite is found covering a strip of country about seven hundred yards long north and south, and from forty to eighty yards wide, on the gradual eastern slope of a hill and on a small spur branching therefrom, to the east. Within this area are many boulders and fragments of ore mingled with fragments of white chert. Some of these boulders are six feet in diameter. The ore is siliceous, silica occurring principally as chert fragments; but the percentage of siliceous material varies largely, portions of the ore being almost free from any silica, while the amount in other portions runs very high. The northern end of the deposit seems to bear the more siliceous ore. This locality is about one mile south of the St. L., C. G. & Ft. S. Ry.

HAWKS (F. T.) AND HON. L. HOUCK LAND (L.).

Sec. 30, T. 27 N., E. 9, and Sec. 25, T. 27 N., 8 E.

Limonite occurs here in the form of rough masses and in an exposed ledge, lying within an area forty yards long and thirty yards wide. These loose boulders and fragments contain cavities, and in these cavities are found argillaceous material and coating of göthite scales. These boulders are in a cultivated field on the cap and western slope of a low knoll, with but little chert and no bedded rock near by. On the western margin of the area, within Sec. 35, a ledge of more massive ore is visible for a distance of nearly twenty-five feet, with the thickness not shown. This ledge is exposed, but a few feet above the small branch. The ore of this deposit is more or less siliceous, containing fine grains of sand. The locality is less than two miles from the St. L., C. G. & Ft. S. Ry.

M'GOWN (JOSEPH) LAND (L.).

Between Secs. 10 and 11, T. 26 N., 8 E.

Scattered boulders of limonite are found here on the northern slope of a hill, covering an area about twenty yards square. The ore is siliceous, silica occurring as small fragments of chert and fine grains of sand. A few blocks and fragments of chert are mingled with the ore boulders. This locality is about two miles distant from the St. L., C. G. & Ft. S. Ry.

PURCELL (H. B.) LAND (L.).

Sec. 36, T. 27 N., 8 E.

Limonite is found here, on the property of Mr. H. B. Purcell, as partially exposed boulders on a rather steep hill slope. But a few of these boulders in the soil are exposed. The ore is siliceous, silica occurring as grains of sand.

SMITH (BENJAMIN) LAND (L.).

N. ½, Sec. 33, T. 27 N., 8 E.

There is quite an extensive outcropping of massive limonite ore, on the property of the heirs of Benjamin Smith and others. It first appears as boulders, fragments and as an apparent ledge, on a moderate hill slope, with boulders here and there over an area perhaps fifty yards in length and seventy yards in width. These boulders are large and small. The ore is siliceous, but the percentage of silica varies in different masses. The silica occurs in the form of fine chert fragments and grains of sand.

Westward from this deposit on the summit of the hill, and again on the crest about two hundred yards further northward, scattered fragments of such ore as was just described, are found. The fragments and small boulders in the northernmost deposit occupy an area which is about sixty yards long and fifteen yards wide. Some scattered fragments of chert occur on all portions of the hill upon which these deposits of limonite are located. These localities are about one mile, or less, north of the St. L., C. G. & Ft. S. Ry.

THELENIUS (G. C.) LAND (L.)

E. ½, Sec. 34, T. 27 N., 8 E.

A deposit of limonite is found here, on the property of Mr. G. C. Thelenius exhibited by boulders and fragments over the surface of an area two hundred and fifty yards in length and from fifty to one hundred yards in width. This surface ore is on moderate slopes of three or four hill spurs and on the summit of the meeting point of these spurs. Over this area much ore is found. Some exploring has been done here and much ore, interstratified with cherty clay, was exposed in the sides of the cuts. The ore is a siliceous ore containing much silica in the form of hard, and partly decomposed chert and scattered grains of sand. This locality is less than half of one mile distant from the St. L., C. G. & Ft. S. Ry.

WOMMACK (D. D.) & CHAPMAN (S.) LAND (L.).

N. E. ¼, Sec. 4, T. 26 N., 8 E.

Here, in the field not far from the summit of a hill, large boulders and an apparent ledge of limonite are exposed over an area about fifteen square yards. The exposed end of the ledge-like mass is about ten feet across with the thickness not shown. The ore is somewhat siliceous, bearing silica in the form of chert fragments and grains of sand. Scattered masses of such ore as this may be found on the slope of this hill for a distance of one-fourth of a mile, westwards. The ore is usually associated with much soil and but rarely is there any rock found within the area containing ore. Lower on the hill there are numerous fragments of white chert. The ore in this part of Sec. 4, is about one mile from the St. L., C. G. & Ft. S. Ry.

REPORTED LOCALITIES.

Mr. Johnson, of near Puxico, reports iron as occurring in the S. E. ¼, Sec. 3, T. 26 N., 8 E., on the property of Messrs. W. I. Smith and Enoch Shoemate.

TEXAS COUNTY.

DUKE (M. E.) LAND (L.).

Sec. 1, T. 30 N., 10 W.

Limonite is found here on a slope of a [illegible]arly flat-topped hill, scattered over several square yards, in the form of r[illegible]gh masses. It occurs with a few boulders and fragments of chert. It is a [illegible]ir quality of iron ore. This locality is twenty miles from the K. C., Ft. S. & M[illegible] Ry.

FIELD BANK (L.).

Sec. 11, T. 30 N., 9 W.

Limonite occurs here over perhaps six[illegible] square yards, on the western slope of a hill, the top of which is in culti[illegible]n and shows quite a large number of boulders of ore and no rock. The o[illegible]the slope lies in two ravines about one hundred yards from the cultivat[illegible]mmit. There seems to be no ledge of ore. Just below, on the hill, [illegible]d limestone is exposed; surrounding the ore are fragments of chert a[illegible]w limestone blocks. This deposit is perhaps twenty miles from the K. C., Ft. S. & M. Ry.

GOVERNMENT LAND NO. 6 (L.).

E. ½, lot 3. N. W. ¼, Sec. 6, T. 29 N., 9 W.

On the side of a hill limonite is found covering half of an acre and within this area little but ore is seen. It is somewhat siliceous, bearing silica as fine grains of sand. In addition to being siliceous it is not compact and hard but contains soft ocherous material. Sandstone in blocks is the principal rock associated with the ore, but no ledge is uncovered. This locality is about twelve miles from the K. C., Ft. S. & M. Ry.

SMALLEY (H. H.) LAND (L.).

Sec. 3[illegible], T. [illegible] N., 11 W.

Limonite occurs here near the foot of a rather steep slope, as scattered boulders, over about half an acre. It is a siliceous ore containing both chert and grains of sand. Much chert is found in the form of large fragments and sharp gravel on the slope adjacent to the area showing ore.

SMITH (N. W.) LAND (L.).

S. E. ¼, S. W. ¼, Sec. 4, T. 30 N., 9 W.

A small amount of limonite is found on the suface at this locality and several shallow pits have been dug here on a very gradual hill slope. These pits are from five to twelve feet deep and, from one or two of these several large boulders of a fair quality of limonite were removed. Some fragments of good ore occur about three hundred yards south, on the slope, associated with limestone. The deposit is situated about twenty-three miles from the K. C., Ft. S. & M. Ry.

SUTTON (T. J.) LAND (L.).

S. ½, N. E. ¼, Sec. 14, T. 30 N., 9 W.

Limonite occurs here in scattered masses on a gradual slope. Two shallow holes have been dug; in one several pieces of iron were found and in the other limestone was reached. This ore is semi-stalactitic in form and of good quality.

REPORTED LOCALITIES.

Messrs. J. L. Goldsberry and T. W. Roberts report the occurrence of iron ore in the N. W. ¼, S. E. ¼, and in N. W. ¼, N. E. ¼, Sec. 18, T 28 N., 11 W.

WASHINGTON COUNTY.

BLANTON LIMONITE BANK (S.).

S. ½, S. W. ¼, Sec. 29, T. 40 N., 1 W.

The limonite bank here is on the southern slope of the Blanton hills. The surface ore occurs in pieces and large boulders and can be traced about one hundred and fifty feet down the slope and sixty feet along the slope. On the hill above the ore sandstone and chert in blocks and fragments occur; in the ravine or branch at the foot of the hill bedded limestone is found exposed.

WAYNE COUNTY.

ATKINS ESTATE LAND (L.).

N. W. ¼, Sec. 19, T. 28 N., 6 E.

Limonite is found here and the main body of the exposed ore extends over an area of about fifty yards square. The ore is slightly siliceous, occurs as fragments on a moderate slope and mingled with many fragments of white chert. Some of the latter are quite large. This locality is about one mile and one-half from the W., G. & N. Ry.

BEAR MOUNTAIN BANK (M.).

N. W. ¼, Sec. 2, T. 29 N., 3 E.

On the base of Bear Mountain, an oblong porphyry hill, limonite is found covering several localities. Detritus of sandy limestone, chert, clay and broken

porphyry cover the base of this hill for about one hundred and twenty-five feet up, and it is in this that the ore is found. These ore localities cover areas from eighty to two hundred and fifty feet long and from twenty to fifty feet wide. Several shafts and cuts have been dug in search of a solid body of ore. The lower cut was run altogether in a light colored clay. The upper one revealed, at the end, a considerable mass of broken limonite lying in cherty clay and a disturbed, decomposed sandy limestone. The shaft above the cut was sunk thirty feet, in light colored clay or decomposed chert passing through a few thin seams of ore, and ending in the clay without reaching any solid body of ore. The upper shaft was only a few feet deep, all in the same clay. The ore in the upper cut is much broken and shattered, and has considerable chert mixed with it. Upon the surface much ore is of stalactitic structure, and quite pure.

BERRY ([illegible]) NO. 1 (L.).

Sec [illegible] N., 6 E.

Here, near the base, on the [illegible] rn slope of a large flat topped hill, occur large and small fragmen [illegible] on ore, the greater portion of which has a rather light brown color, [illegible] nder being of the variety turgite. Some chert fragments are min [illegible] he ore but no bedded rock is visible. About forty yards east of this [illegible] well was sunk and, at a depth of twenty-two feet, four feet of hard [illegible] ore was found. It was supposed that the well just touched the [illegible] tion of the deposit of iron. This information was furnished by [illegible] The distance of this locality from the W., G. & N. Ry. is about five [illegible]

BERRY (WM.) LAND NO. 2 (L.).

S. W. ¼, Sec. 15, T. 28 N., 6 E.

Limonite is exposed here over an area thirty yards long and forty yards wide. Within this area little else than iron ore is to be seen. The ore occurs in fragments and boulders at the foot of the hill. The greater portion is siliceous, containing silica both in the form of small fragments of chert and grains of sand, yet some specimens contain only a small per cent. of silica. About one hundred yards east of this deposit there is a deposit of similar ore. This area is only about twenty yards square. Again, about three hundred yards east, on the same range of hills, a heavy bed of limonite makes up the entire cap of the hill, the exposure being several yards in diameter. Here, again, large boulders and fragments occur, and the ore is quite siliceous. This deposit is seventy-five or one hundred feet higher than either of the other deposits just described. In each case white chert is the only associated surface rock. These localities are about five miles from the Williamsville, Greenville and Northern Ry.

BURDINAUX (WILLIAM) LAND (L.).

N. E. ¼, N. E. ¼, Sec. 36, T. 27 N., 6 E.

Limonite boulders and fragments occur here over an area about seventy-five yards long and thirty yards wide. It occurs from the branch at the foot of

the hill slope and eastward up the slope. The silica contained within these masses is principally in the form of small fragments or particles of chert. No bedded rocks, but fragments and larger masses of chert are found on the surface. On the crest, just east of this deposit, is a small area made up of very sandy iron ore almost so much so as to be termed ferruginous sandstone, and northeast, on a rather low slope, a few masses of good limonite are seen. This deposit is about two miles from the St. L., C. G. & Ft. S. Ry.

THE CEDAR BAY BANK (L.).

Secs. 23 and 14, T. 28 N., 3 E.

This bank is now owned by Mr. J. L. Clarkson, Sr., and the heirs of Judge J. G. Clarkson.

Mining has been done at intervals at this place for a number of years. Clarkson Bros. did some mining in 1882, then Hon. C. D. Yancey carried on the work, shipping the ore to St. Louis. The last mining was done in 1887, by Mr. W. B. Wilcox, and there are left remaining, besides the one long, deep cut, many smaller cuts and shallow shafts at different points and altitudes on this hill, the greater number of which show iron ore.

For a description of the occurrence of and additional notes relative to this deposit see the chapter on Limonite Ores, Part I.

THE DALTON (MRS. N. T.) LAND (L.).

Sec. 11, T. 28 N., 5 E.

Massive limonite occurs here, covering an area about thirty yards square on a gentle slope. The ore is in the form of large fragments. It is siliceous, silica occurring as small angular chert pieces.

This deposit is a little more than one mile from Greenville, which is at the terminus of the W., G. & N. Ry. Several small patches of ore, similar to the one just described, are found on this range of hills.

FOLSOM (ALEXANDER) LAND NO. 1 (L.).

Sec. 2, T. 27 N., 6 W.

Massive limonite is found occurring here on the property of the heirs of Alexander Folsom, covering an area about one hundred yards long and fifty yards wide. The ore here is in huge boulders, scattered on and near the top of a flat hill. These boulders are somewhat porous or spongy. Some of them are found to contain small fragments of white chert, others are almost quite full of chert and contain only a small per cent. of silica in the form of grains of sand. No chert nor bedded rock within the area containing the boulders of ore but just west of the area huge boulders and fragments of chert are seen. This locality is perhaps six miles distant from the St. L., C. G. & Ft. S. Ry.

FOLSOM (ALEXANDER) LAND NO. 2 (L.).

Sec. 2, T. 27 N., 6 E.

This deposit of limonite is about one fourth of a mile north of the deposit just described. The ore is found as a presumable ledge and in scattered large

and small boulders, together covering an area about fifty yards in diameter, on the slope on one side of a ravine. On the opposite side of this ravine, perhaps fifty yards distant, is an area about the same in size, and made up of small boulders and irregular masses of similar ore mingled with fragments of chert. On top of this hill and on the opposite slope scattered boulders are found. The entire area on which ore is found in this locality is about two hundred yards wide and three hundred yards long, though within this area the boulders frequently occur some distance apart. The ore is somewhat silliceous, bearing silica in the form of both sand and fragments of chert. Chert is the only associated rock. This locality is six miles from the St. L., C. G. & Ft. S. Ry.

FOLSOM (ALEXANDER) LAND NO. 6 (L.).

Between Sec. 1[illegible] T. 23 N., 6 E.

Massive limonite is found [illegible] an area ten yards square. The surface ore is in the form of [illegible]rs. It is found to be of a very fair quality. The boulders are at [illegible] a long point and mingled with and above these boulders many la[illegible]ts of white chert are found. This deposit is six miles from the W[illegible] Greenville and Northern Ry.

GARY (A.) AND [illegible] J.) LANDS (L.).

S. W. ¼, Sec. 24, and [illegible]ec. 25, T. 27 N., 6 E.

Limonite is found here in mass[illegible] area about four hundred yards long and nearly fifty yards wide. W[illegible]rea three or four small patches are covered with fragments and bou[illegible]onite. The most southern is at the summit of a rather steep hill nex[illegible]. L., C. G. & Ft. S. Ry., and here the ore is very siliceous, bearing bo[illegible]s of sand and fragments of chert. Then, in a slight depression just north of this hill, there is another area of ore of slightly better quality; and, again about the same distance north, on a lower summit than the first, is still another area of a somewhat superior quality of ore. This area extends about one-hundred yards northward, to the north side of Sec. 25, and continues about seventy yards down a moderate slope in Sec. 24. Here again chert is the only associated rock. The chert occurs on the surface in the form of small chips and boulders.

HAYNIE (S. C.) LAND (L.).

S. W. Sec. 17, T. 27 N., 5 E.

Here several large boulders of limonite are strewn promiscuously over the face of a rather steep hill, on the surface of which are also found scattered boulders and pieces of chert. No bedded rock is exposed. The ore is quite compact, and, but for the small angular fragments of white chert which are cemented by the ore, contains but a small percentage of silica. This small deposit is located but a short distance from the W., G. & N. Ry.

HAYNIE HOLLOW BANK (L.).

Sec. 5, T. 27 N., 5 E.

Massive limonite occurs here about half way up the slope of a moderately steep hill. It is found as boulders, and, in one locality, as what appears to

be a ledge. Portions of the ore are botryoidal. Some of the boulders are porous with ocherous particles and others contain many fragments of chert. The ore covers an area twenty of thirty square yards in extent. It occurs, not with bedded rock, but with chert in the form of loose fragments and boulders. This deposit lies about one mile from the W., G. & N. Ry., about the same distance from the St. L., C. G. & Ft. S. Ry.

HICKS (A. J.) LAND (L.).

Sec. 23, T. 27 N., 6 E.

Limonite occurs here over an area about seventy yards long and twenty yards wide, on a very long slope, near a slough. It is a fine stalactitic ore and occurs as small fragments and large stump-like masses, mixed with fragments and large blocks of chert. It is a good non-siliceous ore. There is no visible bedded rock near. This ore is only about one fourth of a mile from the St. L., C. G. & Ft. S. Ry.

HOLLADAY (H. N.) AND HAYNIE (S. C.) LAND (L.).

Sec. 20, T. 27 N., 5 E.

Limonite boulders, usually about one foot in diameter, and a few larger fragments of ore are exposed here over a small area, on a rather steep slope covered with fragments and boulders of white chert. The ore is somewhat siliceous, silica being contained in the ore masses in the form of scattered grains of sand. This deposit is but a short distance from the St. L., I. M. & S. Ry. and the St. L., C. G. & Ft. S. Ry.

JOHNSON (LEWIS) BANK (L.).

N. E. ¼, S. W. ¼, Sec. 15, T. 28 N., 6 E.

This ore is on the property of Geo. D. Saxton. It is found here covering several square yards on a rather steep slope of a hill. Only a few boulders and chips of ore occur on the surface. This is quite siliceous, containing fine grains of sand. Chert fragments both large and small are found within and adjacent to the area containing surface ore. This deposit is about five miles from the W., G. & N. Ry.

JOINER BANK (L.).

Sec. 19, T. 27 N., 6 E.

This is a bank of coarse, stalactitic and pseudormorph limonite ore on the property of Mr. Jacob Joiner and Mr. W. Davis. The pieces are mainly small and occur on a moderate hill slope with fragments of chert. The area, made up almost entirely of these pieces of ore, is about thirty yards long and fifty yards wide.

West of this deposit, also in Sec. 19 and on the land of Mr. Joiner there is a smaller area of similar ore on the same slope of this range of hills. These deposits are less than one mile from the St. L., C. G. & Ft. S. Ry.

JONES (A. S.) LAND (L.).

Sec. 3, T. 27 N., 7 E.

Here there is a limonite bank with surface ore extending from the lower part of the slope near Mr. Jones residence in a eastward direction, angularly up the slope for a distance of three hundred yards, and with a width of from thirty to sixty yards. Near the western limit are many small sharp pieces and blocks of a somewhat siliceous ore, silica occurring both as grains of sand and fragments of chert. Eastward about two hundred yards the fragments of ore are larger but less numerous. The easternmost portion of the deposit is overlain with large boulders, of slightly porous ore, lying compactly together, thus forming a reef-like deposit. This part of the deposit is about one hundred yards long by fifty yards wide. The ore contains less sand and chert than does that in other portions of the deposit. It does not extend to the highest part of the hill. The surface surrounding the ore is covered with chert pieces and no bedded rocks are seen in this vicinity. Within the area bearing ore only a few fragments of chert are found. Less then one-half mile, across the creek, in an easterly direction from the last, at the foot of a large hill, boulders, and what seems to be a ledge, make up an area which is about thirty yards square. Here the ore is less siliceous, silica occurring only as scattered grains of sand. Loose chert lies on the hill above the ore deposit. These banks are about seven miles from the St. L., C. G. & Ft. S. Ry.

KISTER BANK (M.).

N. E. ¼, N. W. ¼, Sec. 35, T. 30 N., 4 E.

This deposit is on the flank of the same hill as the Yancey Mountain bank described on p. 277 and similar to it in the absence of chert detritus. The ore lies some fifty or sixty feet higher on the hill, upon a ridge between two ravines, and running down into these ravines. At the bottom it is limonite of poor quality, being quite siliceous, but on ascending the hill it grows redder and leaner, and presents the same changes into an apparently decomposed red porphyry that were seen in the deposit above referred to.

MANN BANK (L.).

Sec. 21, T. 27 N., 6 E.

Limonite is found here on the land of Gildehaus, Wulfing and Company, covering an area about forty yards wide and eighty yards long, making up the cap of a steep hill. The ore occurs in fragments both large and small. It is ocherous and siliceous. Some of the fragments containing both chert and grains of sand, others only grains of sand. The slope of the hill is covered with chert fragments, but no bedded rock is visible. This locality is one-fourth of a mile from the St. L, C. G. & Ft. S. Ry.

MASON AND CLARKSON LAND (L.).

E. ½, Sec. 16, T. 27 N., 7 E.

Limonite occurs here over a small area, on a gradual slope of a cherty spur. It is siliceous, silica occurring generally as fine grains of sand. This deposit is about six miles distant from the St. L., C. G. & Ft. S. Ry.

MOSS AND CLARKSON LAND (L.).

N. ½, Sec. 10, T. 27 N., 7 E.

Here scattered limonite boulders and fragments occur on the surface over an area about seven hundred yards long and from fifty to one hundred yards wide, lying, principally, on or near the broad summit of a cherty range. Towards the eastern limit scattered boulders are on the slope and near the crest in an aggregation of boulders and probable ledge. Again, towards the western limit, in the bank of the ravine, not far from the summit, is another ledge-like out-crop more distinctly shown than the ledge near the highest part of the eastern slope. There has been a shallow hole dug from which some ore was taken in clay, but no extensive development of the mode of occurrence of the ore has been made. Some scattering chert fragments are on the hill. This ore is said to be on the land of Mr. T. J. Moss and the heirs of Judge J. G. Clarkson. It is situated about six miles from the St. L., C. G. & Ft. S. Ry.

MAXFIELD (J. C.) LAND (L.).

N. E. ¼, N. E. ¼, Sec. 18, T. 27 N., 6 E.

Here there are two deposits of massive limonite, each about thirty feet in diameter. They form the cap of two high points of a spur and are about fifty yards apart, separated by a shallow depression in which no ore is found, nor does any ore extend far down the slope. In quality the ore is fair, being only slightly siliceous. Lower on the slope, much chert in the form of angular pieces and no bedded rock is exposed. This locality is about three-fourths of a mile from the St. L., C. G. & Ft. S. Ry.

MORITZ (GEO. F.) LAND (L.).

Sec. 12, T. 27 N., 5 E.

There is here a deposit of semi-massive and stalactitic ore. It is about half way down the moderate slope and forms a knoll-like elevation along the slope at this point. The ore is over the surface of an area about fifteen yards square. The greater portion of the ore is in large boulders. The percentage of silica is low in the greater mass of the ore. The silica occurs in the form of grains of sand. This locality is about two miles distant from the St. L., C. G. & Ft. S. Ry.

MORRIS CREEK BANK (M.).

S. E. ¼, Sec. 35, T. 27 N., 4 E.

Here, on the slope of a low hill, about seventy-five feet high, and scattered in the bed of the creek, limonite is found. It lies thickly, about two hundred feet along the slope and extending up to the forty foot level. All the ore is lean and cherty and often little more than ferruginous chert. It seems to have come from a ledge of cherty ore which shows a persistent outcrop at the forty foot level, for about one hundred and fifty feet. The broken surface ore shows a larger proportion of good ore than the solid mass, but even in this there are irregular masses of better ore.

MOSS (T. J.) LAND (L.).

Sec. 19, T. 27 N., 6 E.

Siliceous limonite is found covering an area about fifteen yards square. The ore here is in the form of large boulders. It is siliceous, silica occurring both in the form of chert fragments and grains of sand. Chert fragments occur mingled with the ore boulders but no bedded rock is observed. This locality is but little more than one mile from the St. L., C. G. & Ft. S. Ry.

NEIGHBORS (JOHN) LAND (L.).

S. E. ¼, Sec. [illegible]. 27 N., 7 E.

Limonite is found here covering an area about seventy yards long and thirty yards wide. The ore is in the form of large boulders and fragments and at the southern or lower end of the deposit there appears a reef-like mass or ledge of ore. The deposit is on a divide, sloping southward, between two ridges. The ore is somewhat siliceous, silica occurring both in the form of fine fragments of white chert and grains of sand. The upper portion of this deposit seems to be less cherty than is the ledge. Other boulders of similar ore are seen on the hill at the northern end of the area which bears ore. The hills here have rather steep slopes and, on the surface, scattered fragments of chert are found. The land upon which the ore is located was once homesteaded by Mr. L. T. Dondore with the view of mining the iron ore, but no work has yet been done. This locality is six or eight miles from the St. L., C. G. & Ft. S. Ry., and about the same distance from W., G. & N. Ry.

OTTER CREEK BANK (M.).

S. W. ¼, N. ½, S. E. ¼ of Sec. 3, and lot 1, N. E. ¼, Sec. 4, T. 27 N., 6 E.

Along the top of the range of hills just north of Otter creek there are small outcrops of ore in scattered boulders, but the largest are situated in the N. E. ¼, Sec. 4. Here, upon the southern slope of the hill, near the summit, the ore covers an area about two hundred feet along the slope, and sixty to seventy-five feet wide. Over the crown of the hill, on the northern slope, a small amount of ore is seen. The ore is mostly in quite small pieces, and of poor quality, being sandy and cherty. Upon the S. W. ¼, Sec. 3, lying low on the hill there is a small outcrop of very good stalactitic ore. It is in small pieces.

OZARK LAND COMPANY LAND (L.).

Sec. 17, T. 27 N., 6 E.

Two or three small exposures of limonite are found here. The surface ore is in the form of small fragments and boulders. The fragments are very fair in quality but the boulders are quite siliceous, silica occurring as sand and small chert fragments.

These deposits are about one-half of a mile distant from the St. L., C. G. & Ft. S. Ry.

PETTIT BANK (M.).

S. E. ¼, Sec. 19, T. 27 N., 7 E.

The ore here occurs in two principal outcrops upon the eastern side of a high hill, quite near the top. The southern outcrop shows one mass that appears nearly solid and a large amount broken and scattered down the hill over an irregular area, perhaps one hundred and twenty-five in diameter. The northern outcrop is about two hundred and fifty feet distant, at about the same height, and is smaller but more solid. Some of the ore in the first outcrop is pure and dense, some stalactitic, some very sandy and some cherty. In the northern locality it is porous, sandy and cherty.

RAILROAD BANK (L.).

S. E. ¼, Sec. 8, T. 27 N., 5 E.

Limonite, in the form of fragments, occurs here at the railroad cut near the top of the hill, in the form of small fragments and larger pieces. It covers several square yards but nothing in the cut indicates an extensive deposit, as no ore and only chert and yellow sandy clay are to be seen. Some chert lies on the hill around the area containing ore. It is only slightly siliceous.

REESE CREEK BANK (M.).

Sec. 5, T. 28 N., 6 E.

The ore of this bank shows itself in a zone one hundred feet wide and three hundred feet long, lying across the top of a very high hill or ridge. The largest amount occurs almost at the top of the ridge, where it is in large boulders three feet or more in diameter, but there is no solid mass or dense outcrop appearing nearly solid. The ore is mostly dense, close-grained and of fair quality, although, at places, it is both siliceous and cherty. Some specimens give a reddish streak. Towards the edge of the outcrop it grows more cherty.

RUBOTTOM (L.) LAND (L.).

Sec. 10, T. 28 N., 5 E.

Here a few small masses of limonite are found mingled with many fragments of white chert. The ore is of a good quality, is pseudomorphous, probably after pyrite, and has resinous lustre. No bedded rock near.

SHAW (DAVID) LAND (L.).

W. ½, Lot 1, S. E. ¼, Sec. 6, T. 27 N., 7 E.

A few, slightly cherty and non-siliceous irregularly-shaped masses of hard limonite occur here on the gentle slope. No rock except scattered fragments of chert can be seen in this locality.

SINGER, NIMICK CO. LAND (L.).

Sec. 5, T. 26 N., 5 E.

Here, around the summit and on the gradual slope, boulders and fragments of massive limonite appear. They extend over an area about fifty yards long and thirty yards wide. The ore is of a fair quality, containing some silica in the form of fine grains of sand and, rarely, a fragment of chert. A shallow hole was dug here, several years ago, from which some ore masses were removed but no solid body of ore was reached. Chert, as fragments and scattered boulders, is found on the surface with the ore. This deposit is three or four miles from the St. L., I. M. & S. Ry.

SMITH (PLEASANT) LAND (L.).

W. ½, Lot 1, N. W. ¼, Sec. 6, T. 27 N., 7 E.

Here there is a deposit of limonite, the surface showing of which occupies about half of an acre. This deposit is found on a rather steep slope. Many boulders and chips of ore containing insoluble material, such as grains of sand and small particles of chert, are on the surface. There are fragments of chert lying within the ore area and on adjacent portions of the hill. This deposit is about seven miles from the St. L., C. G. & Ft. S. Ry.

SNEATHEN AND COMPANY LAND NO. 1 (L.).

S. W. ¼, Sec. 8, T. 28 N., 6 E.

Massive limonite occurs here, making up the cap of a hill. The main body of the ore covers nearly an acre of land and this entire area is made up almost wholly of limonite in the form of rough masses and fragments. About fifty yards further east, along the ridge, a smaller area of similar ore occurs and at many places on the hills in this neighborhood scattered masses of ore occur with the chert. This chert is found on all of the hills near here. Much of the ore is of a good quality and contains coatings and thin layers of limonite with a silky to submetallic lustre. There is pseudomorphous ore here. Some fragments contain fine grains of sand.

SNEATHEN AND COMPANY LAND NO. 2 (L.).

Sec. 22, T. 28 N., 6 E.

Massive limonite again occurs here, covering an area of about eighty yards in length and thirty yards in width. The ore here is in the form of large scattered boulders again, making up the cap of the hill. This deposit is two hundred yards southeast of the deposit in Sec. 15 of this same township and the quality of the ore and the mode of occurrence is almost identical in the two localities. Small fragments of ore are found between the deposits but no continuous ledge is apparent.

About one hundred and fifty yards southeast of this deposit, in Sec. 22, there is another, similar deposit, covering an area of perhaps forty yards in width, and twenty yards in length. This ore is also somewhat siliceous, silica occurring

as small angular chert particles and as grains of sand. These localities are nearly five miles from the W., G. & N. Ry. Fragments of similar ore may be found in many places on the hills in Secs. 15, 16, and 22, T. 28 N., 6 E.

SNEATHEN AND COMPANY LAND NO. 3 (L.).

Near the line between Secs. 15 and 22, T. 28 N., 6 E.

Massive limonite is found here, covering an area about one hundred yards long and fifty yards wide, making up the southern portion of a large, flat-topped hill. Many huge boulders, small fragments and an apparent ledge are found within this area. The ore is somewhat siliceous, bearing small fragments of chert and grains of sand. Some of the boulders are porous. On the northern slope of the hill on which this deposit is situated some fragments of chert and water-worn pebbles are found, on other slopes much chert occurs. The main portion of the top of the hill near the ore-bearing area is quite flat, made up of heavy soil and but few rocks. This locality is five miles from the W., G. & N. Ry.

SPEER'S MOUNTAIN (M.).

W. ½, Lot 2, N. W. ¼, Sec. 3, T. 29 N., 7 E.

Limonite occurs here almost exactly on the top or inclining a little towards the eastern slope of a hill. It is in almost solid masses lying irregularly over an area about forty-five feet wide and one hundred and fifty feet along the ridge, while the broken pieces extend down the hill about one hundred feet. The ore is porous and contains chert in small pieces, which occurs at pretty regular intervals. The surface of the hill is covered with soil, and no rock is seen, save occasional chert lumps.

TOWER (GEO. F.) LAND (L).

S. E. ¼, Sec. 16, T. 28 N., 6 E.

Massive limonite makes up an area, here, about ten yards across. Large and small fragments of the ore are found on the gradual slope of a large hill. These fragments are siliceous, silica occurring in the form of partly decomposed chert and fine grains of sand. Small pieces of such ore are found mingled with the chert in many localities on this and neighboring hills. This is nearly five miles from the W., G. & N. Ry.

YANCEY MOUNTAIN BANK (M.).

N. W. ¼, N. E. ¼, Sec. 35, T. 30 N., 4 E.

Limonite ore is found here at the foot of a porphyry hill, lying scattered in large and small pieces upon the porphyry and porphyrytic detritus. Little or no chert or clay is present, and the ore is singularly free from chert. At the lower part of the outcrop the ore is brown in color, free from impurity. Higher up it grows more siliceous and darker in color, and finally has the appearance of a decomposed porphyry, highly ferruginous.

REPORTED LOCALITIES.

Mr. S. C. Haynie, of Williamsville, reports iron as occurring in S.W. ¼, N. E. ¼, Sec. 17, T. 27 N., 5 E.; in Sec. 9, T. 27 N., 5 E., on the property of Mr. B. Bossanbin; in Sec. 12, T. 27 N., 5 E., also on the property of Mr. Bossanbin, and in Sec. 4, T. 27 N., 5 E., and Sec. 29, T. 27 N., 5 E.

Mr. James F. Hatten, of Williamsville, reports limonite as occurring in Sec. 35, T. 28 N., 5 E., on the property of Clarkson and Mason, and another in the same section on the property of Mr. H. N. Holladay; in Sec. 26, T. 28 N., 5 E. and in Sec. 30, T. 28 N. 7 E., on property of Mr. Perry Bennett.

Mr. E. P. Settle, of Greenville, reports iron ore in S. W. ¼, Sec. 5, T. 28 N., 6 E., on property owned by Mr. H. N. Holladay; in S. ½, Sec. 5, T. 27 N., 5 E., on property belonging to the heirs of Judge J. G. Clarkson; in Sec. 6, T. 27 N., 8 E., on the land owned by Mr. T. J. Moss; near the center of Sec. 17, T. 27 N., 6 E., and in Sec. 7, T. 27 N., 6 E.

Also a deposit of pipe ore in Sec. 7, T. 27 N., 6 E., on the property of Mr. Jos. D. Deaton.

Mr. T. A. Johnson, of Piedmont, reports a small deposit of limonite in Sec. 23, T. 29 N., 3 E.

Mr. Wm. Page reports the occurrence of iron ore in Sec 21, T. 27 N., 6 E., on the property of Mr. Hanlan of St. Louis.

Dr. J. L. Allison, of Chaonia, reports iron ore as occurring in the following localities; in N. ½, N. W. ¼, Sec. 36, T. 27 N., 6 E., on land belonging to Mr. L. S. Osgood; in N. W. ¼, S. E. ¼, Sec. 25, T. 27 N., 6 E. on land homesteaded by Mr. E. G. Boucher; in S. W. ¼, N. E. ¼, Sec. 26, T. 27 N., 6 E., on the property of Mr. A. Gary; in W. ½, N. E. ¼, Sec. 25, T. 27 N., 6 E., on the property belonging to Mr. T. J. Moss.

CHAPTER XI.

THE RED HEMATITES.

CALLAWAY COUNTY.

DUNN (RICHARD) BANK (S.).

Sec. 21, T. 46 N., 10 W.

Strata of red hematite are perceptible three miles north of New Bloomfield, on the road to Fulton. The ore crops out in the road for a distance of about twelve feet down the slope. Sandstone is seen above and below the ore. One quarter of a mile west, on the same slope and level, stratified ore has been found immediately below the soil.

DUNN (RAPH) BANK (N.).

Sec. 32, T. 40 N., 10 W.

For a description of this deposit, see Chapter IV, of this report.

HENDERSON BANK (S.).

Sec. 12, T. 45 N., 11 W.

Here numerous and rounded surface ore is seen in several places on the two hills, west of the road; loose surface ore along the road on the northern slope of the eastern hill; a small and indistinct outcrop of stratified ore at the foot of this hill, near the ravine, and finally loose surface ore in the ravine. The two western hills are composed of Encrinital limestone which is laid bare in several places and seems to reach the summits. Loose ore has been ploughed up on the plateau on the northern hill. The ore is dark red, fine grained hematite in thin layers, and is associated with layers of chert. The exposure extends over a few feet only.

KNIGHT BANK (S.).

Sec. 2, T. 46 N., 10 W.

Here a fine outcrop of dense and fine grained hematite is seen on the eastern slope of a low hill. The ore is more than two feet thick. It can be seen in only two places, about twenty feet apart. Due east of this hill, small and large pieces and plates of ore are found loose in the bed of Middle Auxvasse creek. On the low hill just south of the hill, on which ore was just described as occurring, outcrops of ferruginous sandstone overlaid by thin seams of red ore are noticed. These outcrops are on both the northern and southern slopes.

MURPHY'S HILL (S.).

Sec. 15, T. 45 N., 10 W.

Here no ore is to be seen in place, but large, somewhat rounded pieces and plates of red ore are found in two ravines. The hill itself seems to be composed of sandstone. Large masses of limestone are, however, projecting from the lower part of the slope, apparently between the sandstone.

OLD DIGGINGS (S.).

Sec. 22, T. 45 N., 10 W.

Here the lower part of the hill [illegible]o be composed of sub-carboniferous limestone, the upper of ferruginous [illegible]tone. Large and small fragments of chert are found all over the grou[illegible]e red hematite has been discovered near the top of the hill, on both [illegible]f the ravine. On the western, a hole was dug a number of years ago an[illegible]aid many tons of ore were taken out. On the east of the ravine, and rath[illegible] to it, an outcrop is perceptible, consisting of a five-inch stratum of so[illegible]e, red hematite. The total thickness cannot be seen.

SHAFT [illegible]L (S.).

N. W. ¼, Sec. [illegible] 45 N., 10 W.

Near the summit of a nearly ro[illegible]ill red hematite occurs in nodules or lenticular concretions, composed [illegible]ral concentric layers, and apparently imbedded in loose sand, sometim[illegible]in layers, alternating with layers of loose sand, sometimes as thick, massiv[illegible]strata. A shaft was dug about thirty years ago on the eastern slope of the hill near a ravine, at a level considerably below the regular ore-bed. This shaft went eight feet through sand and broken ore and chert. Under the regular ore bed there is conglomerate of chert and sandstone, sandstone and limestone; above it occurs chert and soil.

HENRY COUNTY.

BROWN BANK (S.).

This bank is situated on the dividing ridge between Osage and Grand rivers. Red, earthy hematite, partly changed into brown and yellow limonite, is found on the surface here over a very large area, associated with ferruginous sandstone.

OTHER DEPOSITS.

For a description of deposits at other localities in Henry county, see Chapter IV, of this report.

ST. CLAIR COUNTY.

COLLINS BANK (S.).

Sec. 23, T. 39 N., 25 W.

An outcrop of red, earthy hematite, portions of which are somewhat argillaceous, extends over a distance of two hundred feet, along the ravine at the foot of a steep slope, on which no rocks are perceptible, except broken chert above the soil.

GROVER BANK (S.).

Sec. 16, T. 39 N., 24 W.

Large and small fragments of ferruginous sandstone, frequently very rich in iron, together with some brown and red hematite, are spread over a zone several hundred feet wide, and about one fourth of a mile long across a limestone ridge.

MARMADUKE BANK (S.).

Sec. 23, T. 39 N. 25 W.

Fragments of earthly, red hematite partly altered into yellowish brown, porous limonite, are found on the surface on the summit of the ridge, over an area measuring six hundred feet across, and four hundred feet along the ridge. Some of the ore is sandy and passes into a regular ferruginous sandstone in places. Most of the ore is good and the fragments large and sharp-edged.

OTHER COUNTIES.

For a notice of occurrences of red hematite in Monroe, Lincoln, Cooper, Saline and Benton counties, see Chapter IV, of this report.

APPENDIX A.

THE IRON DEPOSITS OF NORTHEASTERN ARKANSAS.[1]

Extract from the Report on the Iron Deposits of Arkansas, by R. A. F. Penrose, Jr., Ph. D.; being Chapter II, of Volume I, of the Annual Report for 1892 of J. C. Branner, State Geologist of Arkansas.

LAWRENCE, SHARP, FULTON, AND RANDOLPH COUNTIES.

THE LOCATION OF THE DEPOSITS.

The iron ores of northeastern Arkansas occur mostly in the counties of Lawrence, Sharp, Fulton and Randolph, in the hilly country comprising the valleys of the Black river and its tributaries, the Strawberry, Spring and Eleven Points rivers. This region includes an area over 50 miles long in an east and west direction, and about 35 miles wide in a north and south direction. The ore does not occur continuously throughout it, but exists as isolated deposits separated by much greater areas destitute of ore.

The area of the limonite region.

THE GEOLOGIC RELATIONS OF THE DEPOSITS.

The ores occur with a series of cherts, limestones and sandstones which form a part of the Lower Silurian series of northern Arkansas. The exact position of these rocks in the Lower Silurian is somewhat doubtful, but, from the studies of the State geologist and Prof. H. S. Williams, it is probable that they belong in or below the Calciferous horizon. They dip under the saccharoidal sandstone and the Izard and St. Clair limestones which represent the upper members of the Lower Silurian system in the Batesville manganese region to the south of the iron region.[2]

Limonites occur with sandstones and limestones.

[1] This extract from the Arkansas report is introduced here for the sake of completeness. It, together with the chapter on the same ores of the preceding report, constitutes a complete description of the limonites of the region. Dr. Penrose's discussion adds further much of interest and value bearing upon the composition and geology of the Missouri limonites.—A. W.

[2] The geologic relations of these rocks are more fully discussed in the

THE NATURE OF THE ORES.

The iron ores of northeastern Arkansas all belong to the class of hydrous sesquioxides of iron, known as limonite, brown hematite or simple "brown ore." Seventeen analyses of these ores, made by the Geological Survey, Prof. A. E. Menke, chemist, are given in the accompanying table. It will be seen that the amount of iron varies from 23 to 58 per cent. In samples 1, 2, 11, 12 and 15 it is over 50 per cent., and is good for a brown hematite ore. The percentage of silica also varies considerably. Samples 1, 2, 3, 11 and 12 ar[illegible] in silica; samples 6 and 7 are rendered undesirable on account of their high percentages of silica; while samples 4, 5, 9, 10, 13 and 14 are practically ruined by their high contents of this ingredient.

In phosphorus also samples are variable, some being low enough to be classed as Bessemer, while others are too high. An ore is too high in phosphorus to be used for Bessemer steel if it contains more than about 0.05 per cent. of that ingredient (see pages 8 and 10). It will be seen that several of the samples contain less than that amount. Sufficient analyses, however, have not been made of the ore on any one property to state that the whole deposit would be low enough in phosphorus to make Bessemer steel, as it is perfectly possible that a sample from one part of a deposit may be low in phosphorus, while another from a few yards off may be high. The average contents of a deposit in phosphorus can only be determined by carefully prospecting and stripping the ore and making numerous analyses, all of which have been beyond the means and the time of the Survey. The low phosphorus, therefore, in some of the analyses, can be regarded only as a valuable indication and not necessarily conclusive as to the quality of the whole deposit.

The sulphur is not excessively high in any of the samples analyzed.

Considering all the constituents of the ores, it may be said that samples 1, 2, 3, 11, 12 and 15 are good ores, while the rest of the samples represent ores more or less injured or even ruined

Annual Report of the Geological Survey of Arkansas for 1890, Vol. I, pp. 112-116.

by the low percentage of iron or by excessive quantities of impurities.

The ores vary much in physical character. In color they range from light yellow to chocolate brown, or even almost black, and are often coated with a glossy black film. They often contain considerable quantities of sand which can be seen in grains scattered through the mass; and in the more siliceous varieties the sand increases in quantity until the ores merge into a ferruginous sandstone. Between the pure ore and the ferruginous sandstone there are all degrees of admixture. Sometimes the ore is massive and solid, at other times porous and honey-combed, while not infrequently it occurs as geodes, commonly called "iron pots," from an inch to a foot or more in diameter. Elsewhere the ore occurs as the cement of the brecciated chert.

Physical characteristics of the ore.

ANALYSES OF IRON ORES FROM NORTHEASTERN ARKANSAS.

Analyses.

Number.	Locality.	Iron.	Silica.	Phosphorus.	Sulphur.	Manganese.	Analyst.
	LAWRENCE COUNTY.						
1	Coffman tract, 17 N., 1 W., Sec. 17, S ½, S. E. ¼...	55.75	5 20	0 041	0.212	Little.	Menke.
2	Holloway tract, No. 1, 16 N., 2 W., Sec. 6, S. E. ¼.	53.91	7.08	0.028	0.198	"	"
3	Holloway tract, No. 2, 17 N., 3 W., Sec. 35, N. E. ¼, S. E. ¼	45.49	8 47	0.007	0.315	"	"
4	Cazort tract, 16 N., 2 W., Sec. 6, N.W. ¼ S.W. ¼ ...	41.71	28.26	0.014	0.232	"	"
5	Holloway & Collins tract, No. 1, 16 N., 3 W., Sec. 12, S. E. ¼	49.44	25 85	0.028	0.479	"	"
6	Holloway & Collins tract, No. 2, 16 N., 3 W., Sec. 12, W. ½, W. ½..........	47.99	15 08	0.083	0 051	"	"
7	Wasson tract, No. 1, 17 N., 3 W., Sec. 26, S. ½....	41.58	16.26	0.193	0 095	"	"
8	Sloan tract, 17 N., 3 W., Sec. 28, W. ½, N. E. ¼....	40.10	12 54	0.042	0 637	"	"
9	Strawberry or Cathaytown, 16 N., 3 W., Sec. 12, S. E. ¼..........	36.80	30 87	0.041	0 205	None.	"
10	Strawberry or Cathaytown, 16 N., 3 W., Sec. 12, S. E. ¼..........	27.35	52 58	0.284	0.034	"	"
	SHARP COUNTY.						
11	Collins tract, 16 N., 4 W., Sec. 8, S. W. ¼..........	58.91	2.46	0 088	0.109	Trace.	"
12	Wasson tract, No. 2, 16 N., 4 W., Sec. 13, E. ½, S. E ¼..........	54 70	2.80	0 021	0.458	None.	"
13	Big Creek and Reed's Creek divide, 16 N., 4 W., Sec. 36, N. ½..........	23 67	58 12	0 306	0.178	"	"
	FULTON COUNTY.						
14	Deadrick tract, 20 N., 6 W., Sec. 1..........	44 97	21.40	0 031	0.109	"	"
	RANDOLPH COUNTY.						
15	Near Ravenden Springs	50.49	12 60	0.041	0 102	Little.	"
16	Odom tract, 18 N., 1 W., Sec. 18, N. E. ¼, N. E ¼	44 44	11.83	0.021	0.157	"	"
17	Iron Bank, 21 N., 3 W., Sec. 8, N. E. ¼, S. W. ¼...	49 97	14.53	0 014	0.082	Trace.	"

THE MODE OF OCCURRENCE OF THE ORES.

The general character of the region in which the iron ores of northeastern Arkansas occur, is that of a rolling country with hills and ridges rising from one to over three hundred feet above the surrounding drainage, and separated by flat river and creek bottoms. The hills and ridges often rise abruptly from the lowlands and the ridges follow a circuitous course for many miles across the country. Such ridges are well seen between the Spring and Eleven Points rivers in Randolph county, between Big Creek and Reed's Creek in Sharp county, and elsewhere.

The iron ore usually occurs on or near the tops of the hills and ridges, though more rarely it is lower down on the slopes. The lower parts of the hills and ridges are composed of a blue limestone which underlies the larger portion of the low country and is the predominating rock of the region. This bed and also the other rocks of the region are practically horizontal, though they sometimes dip gently to the south. A thickness of limestone over 200 feet is often exposed on the slopes of the hills, and as it still underlies the lowlands, it is probably thicker. Above the limestone on the slopes of the hills comes a sandstone which generally forms the summit, at least of the higher points, and varies in this position from a few feet to almost if not quite 100 feet in thickness. Sometimes the sandstone does not occur, and the hills are capped with a gray chert which often partakes of the nature of the sandy quartzite. In the cases where both the sandstone and the chert occur in the same localities, the chert underlies the sandstone, and overlies the blue limestone. Where the chert is wanting the sandstone comes into direct contact with the limestone. It is noticeable that, though the limestone is apt to contain cherty masses anywhere through it, the formation becomes more cherty towards the top. It seems probable that when the chert intervenes between the sandstone and the limestone, it simply represents an unusually large development of this cherty character of the top of the limestone. This would account for its sudden appearance and disappearance, since sometimes it has a thickness of probably 75 feet or more,

while elsewhere it is wanting altogether, and the sandstone comes into direct contact with the underlying limestone.

Where the sandstone has been eroded from the hills and ridges and the chert covers the highest points, the summits have the character and rough appearance of a surface covered with broken masses of rock. Not infrequently the chert is abruptly cut off by a protrusion of limestone which comes to the top of the hill and locally forms the crest, while beyond, along the summit, the chert appears again. This sequence of outcrops is a natural result when it is considered that the chert exists simply as large pockets and lenticular layers in the limestone, and may be cut out by that rock at any point.

Relations of limestone and chert.

The iron ore occurs in both the chert and the sandstone; and as either one or the other of these rocks usually forms the crest of the hills and ridges, the ore is generally near the summits. It does not form a continuous bed over any very large area, but

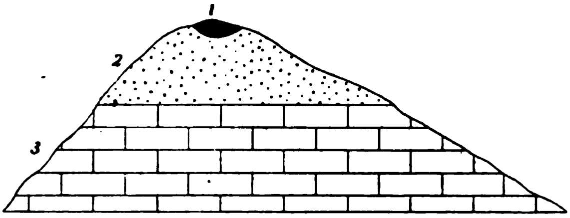


FIG. 60 (FIG. 1 of Ark. report). Section across Iron Mountain on the Collins tract, Sharp county, showing the mode of occurrence of the iron ore.

1. Iron ore (limonite).
2. Sandstone.
3. Limestone.

Horizontal scale. 1 inch = ¼ mile. Vertical scale: 1 inch = 100 feet.

occurs in more or less isolated basin-shaped deposits, varying from a few square yards to several acres in extent and from two to three feet to probably over twenty-five feet in thickness. The section in Fig. 1 represents a typical case of the iron deposits of northeastern Arkansas, as exemplified in Iron Mountain on the Collins tract in Sharp county. This tract will be more fully described later in the present chapter.

Iron deposits generally on the crests.

In following along any of the ridges in the iron district a series of such basin-shaped pockets as have just been described are seen, separated along the ridge by areas of barren sandstone

or chert. Sometimes the ore is comparatively pure, at other times it simply forms the coloring matter and cement of ferruginous sandstone or binds together the fragments of chert breccia; and almost always more or less sandy impurities can be seen in it. Sometimes the ore forms interbedded, alternating layers with a ferruginous sandstone, or occurs in bunches in the sandstone or chert. A common occurrence is a chert bed cut by a network of bunches and connecting seams of ore.

Impurities in the ore.

Frequently where the sandstone or chert is soft, the rock has decayed, forming a red clay in which the masses of ore are imbedded. Such deposits often afford a good soil and at the present time many of the iron ore tracts are cultivated as farms, and the lumps of ore are constantly being plowed up. This is especially well seen in the neighborhood of Smithville in Lawrence county, and around Calamine in Sharp county. Occasionally also the ferruginous waters from springs in the iron ore hills have cemented the sand and gravel in the creek beds, forming a ferruginous conglomerate, which is of course of much later age than the iron ore in the hills.

THE COMMERCIAL VALUE OF THE DEPOSITS.

The facilities for mining iron ore in northeastern Arkansas are fairly good. The ore, occurring as it does on the tops of the isolated hills and ridges, though limited in both vertical and lateral extent, could be easily mined. The nearest means of transportation is the Kansas City, Fort Scott and Memphis railway, which is from [illegible] to twenty miles distant from the more [illegible] deposits. In some cases freight could be shipped [illegible] White river, and thence to the Mis- [illegible] by wagons of from ten to twenty [illegible] The nearest coking coal to the iron [illegible] Arkansas and Indian Territory at [illegible] miles. [illegible] in the vicinity of the [illegible] deposits [illegible]

deposits combines a fairly good quality with sufficient quantity to allow it to be mined.

In view of all of these conditions it may be said that there is a chance of the profitable working of some of the iron deposits of northeastern Arkansas. Deposits may prove profitable for working.

Below are given descriptions of the individual properties in the iron region of northeastern Arkansas.

LAWRENCE COUNTY.

General Features. The iron ores of Lawrence county are mostly west of the Black river, in the western part of the county. They extend from near Black Rock on the Black river, west into Sharp county and south to and beyond the Strawberry river. This area includes most of the deposits that are known, though others of less importance are found elsewhere in the county.

The J. W. Coffman Tract. The Coffman tract is in 17 N., 1 W., section 17, the south half of the southeast quarter, about a mile west of Black Rock. A brown hematite ore occurs in loose masses here associated with fragments of chert in a red and white clay. It is found over an area of probably six or seven acres. The deposit is so much concealed by soil that it is impossible to determine accurately its size and extent without more prospecting than has been done. The only opening that has been made is a small pit about six feet deep showing masses of ore in the clay. Some of the ore contains siliceous pebbles and this may be, in part at least, a later deposit than the ore free from pebbles. The Coffman tract.

The following analysis by A. E. Menke shows the composition of the ore from this property :—

ANALYSIS OF IRON ORE FROM THE COFFMAN TRACT, LAWRENCE COUNTY.

Iron	55 75
Silica	5.20
Phosphorus	0.041
Sulphur	0.212
Manganese	a little.

The analysis shows the ore to be of good quality, but the quantity of it on the property has yet to be proved.

P. Holloway tract No. 1. *The S. P. Holloway tract No. 1.* This is one of the several tracts of iron ore land owned in this region by Mr. S. P. Holloway of Black Rock. It is in 16 N., 2 W., section 6, the south-east quarter. The brown hematite ore occurs here in loose masses in the soil on the summit of a hill. It is associated with fragments of sandstone and quartzite, and the exposed masses of ore have probably been set free during the disintegration of these rocks, in which they were probably originally held. The ore is sometimes sandy and is occasionally found adhering to masses of sandstone. It sometimes occurs as hollow "pots," and at other times as a massive ore with a banded, agate-like structure. A few small prospecting pits show masses of ore imbedded in the red soil.

The following analysis by A. Menke shows the composition of the ore from this property:—

ANALYSIS OF IRON ORE FROM THE S. P. HOLLOWAY TRACT NO. 1, LAWRENCE COUNTY.

Iron	58.91
Silica	7.08
Phosphorus	0.028
Sulphur	0.198
Manganese	a little.

The analysis shows the ore to be of very good quality. It is comparatively high in iron, exceptionally low in phosphorus and comparatively low in silica. Thus analysis, however, cannot be considered as representing the quality of the whole deposit. The property is heavily covered with soil, and when the sample for the analysis was taken only a limited part of the whole ore bed was accessible. To test the deposit properly it should be stripped in a large number of places and numerous samples should be taken for analysis. In this way both the quality and quantity of the ore could be determined, a thing which in the present unprospected condition of the property it is impossible to do.

Cazort tract. *The Cazort Tract.* The Cazort tract is in 16 N. 2 W., section 6, the northwest quarter of the southwest quarter, and in section 7, the northeast quarter of the southeast quarter. It is close to the last mentioned property and the ore occurs under very much

the same conditions as on that tract, except that it is more sandy and therefore contains a larger percentage of silica, as shown by the following analysis by A. E. Menke: —

Analysis of the Cazort ore.

ANALYSIS OF THE IRON ORE FROM THE CAZORT TRACT, LAWRENCE COUNTY.

Iron	41.71
Silica	28.26
Phosphorus	0.014
Sulphur	0.232
Manganese	a little.

The analysis shows the ore to be low in iron and injuriously high in silica.

The Holloway and Collins Tract No. 1. The Holloway and Collins tract No. 1 is in 16 N., 3 W., section 12, the southeast quarter, and is locally known as Iron Mountain. The brown hematite crops out for a distance of half mile on the summit of a ridge running in a general north and south direction. The base and lower slopes of the ridge are composed of blue limestone lying almost horizontally, while the sandstone with more or less chert and quartzite appears on the upper part. The sandstone is in some places white, and in others rusty brown from the presence of iron. The ore occurs in isolated basins or in large irregular pockets in the sandstone, and in following along the top of the ridge ore may be found in one place and perhaps a few yards further on sandstone crops out, to be cut off by ore again beyond, thus causing an alternating series of outcrops of ore and sandstone. So little prospecting has been done on the property that it is impossible to determine the thickness of the deposit or, in fact, anything more than its most general features.

The Holloway and Collins tract, No. 1.

The following analysis by A. E. Menke shows the composition of the ore :—

ANALYSIS OF IRON ORE FROM THE HOLLOWAY AND COLLINS TRACT NO. 1, LAWRENCE COUNTY.

Analysis of the ore.

Iron	49.44
Silica	25.85
Phosphorus	0.028
Sulphur	0.479
Manganese	a little.

The analysis shows the ore to contain an injuriously large percentage of silica.

oway llins No. 2.

The Holloway and Collins Tract No. 2. The Holloway and Collins tract No. 2 is in 16 N., 3 W., section 12, the west half, and shows ore somewhat like that on the last property. It is covered with so much soil, however, that it is impossible to determine accurately the extent of the deposit. A pit about twenty feet deep was sunk at this place some years ago. It is now mostly filled with earth, but the upper six or seven feet are still open. It shows alternating layers of ore and ferruginous sandstone, the thickest layer of solid ore seen being about two feet. Sometimes layers and pockets of red clay occur in the ore. The ore dips apparently at about 30° to the southwest, but this may be simply due to a local slip in the surface rocks. It is probable that further prospecting on this property would show considerable series of alternating layers of sandstone and ore.

The following analysis by A. E. Menke shows the composition of the ore on this property:—

of the

ANALYSIS OF IRON ORE FROM THE HOLLOWAY AND COLLINS TRACT NO. 2, LAWRENCE COUNTY.

Iron	47.99
Silicia	15.08
Phosphorus	0.083
Sulphur	0.054
Manganese	a little.

This analysis shows the ore to be fairly good in its contents of iron, somewhat injured by the high percentage of silica, and to contain too much phosphorus to be classed as a Bessemer ore.

. Hollo act. No. 2

The S. P. Holloway Tract No. 2. The Holloway tract No. 2 is north of the last mentioned property and in 17 N., 3 W., section 35, the northeast quarter of the southeast quarter. A porous brown hematite, often in the form of "iron pots," occurs here in a red and brown clay in the bluff of a small creek. The masses of ore, which are sometimes two or three feet in diameter, often form horizontal layers in the clay. A pit said to be twenty feet deep was sunk here some time ago, but, now filled

up to within eight feet of the surface. The exposed sides of the pit show a face of ore in red and gray clay over five feet thick. This is underlain by clay, below which more ore is said to have been found in the old pit. About ten feet of ore altogether is said to have been exposed.

Analysis of Holloway ore.

The following analysis by A. E. Menke shows the composition of the ore from this property:—

ANALYSIS OF ORE FROM THE S. P. HOLLOWAY TRACT NO. 2, LAWRENCE COUNTY.

Iron	45.49
Silica	8.47
Phosphorus	0.007
Sulphur	0.315
Manganese	a little.

The analysis shows the ore to be somewhat low in iron, but good in other respects.

The Wasson Tract No. 1. The Wasson tract No. 1 is in 17 N., 3 W., section 26, the south half. This property is on the continuation of the same ore belt as the last mentioned property, and shows ore occurring under somewhat the same conditions. The ore is often composed of geodes, or "pots" of brown hematite, from one to six inches in diameter, and held together by a ferruginous cement. The following analysis by A. E. Menke shows the composition of the ore from this property:—

The Wasson No. 1.

ANALYSIS OF THE IRON ORE FROM THE WASSON TRACT NO. 1, LAWRENCE COUNTY.

Analysis of the ore.

Iron	41.58
Silica	16.26
Phosphorus	0.193
Sulphur	0.095
Manganese	a little.

The analysis shows the ore to be low in iron and high in silica, though other samples from this property might give better results.

The Moore Tract. The Moore tract is in 17 N., 3 W., section 21, the southeast quarter of the southeast quarter. It shows ore occurring under much the same conditions as on the Wasson tract, which lies northwest of it.

C. Sloan

The W. C. Sloan Tract. The Sloan tract, commonly known as High Peak, is in 17 N., 3 W., section 28, the west half of the northeast quarter. High Peak is a small knob rising from the crest of a ridge and reaching between two and three hundred feet above the surrounding drainage. The lower part of the hill is mostly limestone while the crest of the knob is capped with chert, which outcrops in a loose broken mass. Fragments of brown hematite occur with the loose chert on the summit, and have undoubtedly been derived from a small pocket of ore in that rock. One small opening about three feet deep has been made. The ore is small in quantities, the fragments occurring scattered over only about half an acre.

The following analysis by A. E. Menke shows the composition of the ore:—

ANALYSIS OF IRON ORE FROM THE W. C. SLOAN TRACT, LAWRENCE COUNTY.

...s of the

Iron	40.10
Silica	12.54
Phosphorus	0.042
Sulphur	0.637
Manganese	a little.

The analysis shows the ore to be low in iron.

Strawberry ...thaytown.

Strawberry, or Cathaytown. The village of Strawberry, also known as Cathaytown, is on the south side of the Strawberry river, in 15 N., 3 W., section 5. A brown ferruginous sandstone covers several of the hills in the village, forming numerous rounded, rocky knobs, and is commonly mistaken for iron ore. Occasionally a few small masses of a sandy brown hematite occur in the rock, but the vast bulk of what is commonly supposed to be ore is simply a rusty sandstone, of no value whatever as an iron ore. Similar materials exist in many other places near Strawberry.

The following analyses by A. E. Menke show the composition of this material:—

ANALYSES OF IRON ORE FROM STRAWBERRY, LAWRENCE COUNTY.

...ses of ore.

Iron	36.30	27.35
Silica	30.87	52.58
Phosphorus	0.041	0.284
Sulphur	0.205	0.034
Manganese	none.	none.

These analyses show the so-called iron ore of Strawberry, or Cathayton, to be so low in iron and so high in silica that it is worthless as a source of iron.

SHARP COUNTY.

General Features. The iron ores of Sharp county, so far as known, lie mostly south of the Strawberry river, in the southern part of the county, though other deposits occur north of this area.

The Collins Tract. The Collins tract is in 16 N., 4 W., section 8, the southwest quarter. It is locally known as the Iron Mountain, which is the top of a ridge rising almost 200 feet above the surrounding drainage. The lower part of the hill, for about 90 feet from the base, is composed of the blue limestone common to the region. The upper 85 feet are composed of sandstone, often assuming a quartzitic nature. The ore occurs in fragments on the summit, and is associated with the sandstone, from which the masses have been derived. The ore covers about two acres and is found more sparingly beyond these limits. It evidently represents a basin-shaped deposit in the sandstone. A pit, mostly filled up, is said to have been ten feet deep and to have gone through ore all the way. The ore is a brown hematite, often occurring as a mass of small nodules, the size of a pea or larger, with a fibrous structure, radiating from the center. Elsewhere the ore is simply the common porous and honey-combed brown hematite. The Collins tract.

The following analysis by A. E. Menke shows the composition of the ore:—

ANALYSIS OF THE IRON ORE FROM THE COLLINS TRACT, SHARP COUNTY. Analysis of the ore.

Iron	58.91
Silica	2.46
Phosphorus	0.083
Sulphur	0.109
Manganese	trace.

The analysis shows a very good ore for non-Bessemer purposes, though the phosphorus is too high to permit it to be used for

Bessemer steel. The quantity of the ore, however, from a commercial stand-point, has yet to be determined.

Wasson tract No. 2.

The Wasson Tract No. 2. The Wasson tract No. 2 is in 16 N., 4 W., section 13, the east half of the southeast quarter. The land here is mostly under cultivation and heavily covered with soil. The ore occurs as masses in red clay and is only seen where it has been plowed up. The property is only half a mile north of the Bevens bloomary, where iron was made before 1860 (see page 2), and a part of the ore used in the bloomary is said to have been mined on this tract. At present the old pits have been filled up and but little can be seen of the ore.

The following analysis by A. E. Menke shows the composition of the ore: —

ANALYSIS OF THE IRON ORE FROM THE WASSON TRACT NO. 2, SHARP COUNTY.

Iron	54.70
Silica	2.80
Phosphorus	0.021
Sulphur	0.458
Manganese	none.

The analysis shows the ore to be of a very good quality, high in iron and low in silica and phosphorus, but the quantity of the ore is doubtful. An ore that seems to be similar to that on the Wasson tract occurs in 16 N., 4 W., section 24, the east half of the northeast quarter.

The Big Creek and Reed's Creek Divide. Big creek and Reed's creek both rise in the southern part of Sharp county and flow [illegible] into the Strawberry river in Lawrence [illegible] east of the dividing line between the two [illegible] ridge, often rising over one hundred [illegible] surrounding drainage, forms the divide [illegible] creeks. It is composed of [illegible] and is capped with a [illegible] and [illegible] thickness. This [illegible] summit of [illegible]

ridges it is found that the character of the sandstone varies much in different places, often changing abruptly from a pure white rock to one stained dark brown by iron, the latter dark rock representing simply local, isolated patches in the white variety. This ferruginous sandstone is often mistaken by the people living in the vicinity for iron ore, but it contains too much sand and too little iron to be of any value as such. Occasionally small masses, seams or pockets of a genuine ore in the form of a brown hematite occur in the ferruginous sandstone, but this is in only very small quantities and could not be profitably separated. The great mass of the so-called ore is simply a rusty sandstone.

Ferruginous sandstone taken for ore.

Such deposits are well seen in several places on the Big creek and Reed's creek divide, especially in 16 N., 4 W., section 36, the north half, and in section 25, the south half. The following analysis, by A. E. Menke, of a sample of the material from the first named locality, shows its composition:—

ANALYSIS OF IRON ORE FROM THE BIG CREEK AND REED'S CREEK DIVIDE, SHARP COUNTY.

Analysis of ferruginous sandstone.

Iron	23.67
Silica	58.12
Phosphorus	0.306
Sulphur	0.178
Manganese	none.

The analysis shows the material to be too low in iron and too high in silica to be of any value whatever as an iron ore.

FULTON COUNTY.

General Features. The iron ores of Fulton county, so far as known, occur mostly in the region between Spring river on the east and a few miles beyond the town of Salem on the west. Among the best known localities is the Deadrick tract.

The Deadrick Tract. The Deadrick tract is in 20 N., 6 W., section 1. The ore is a brown hematite and occurs in association with a bed of chert on the crest and upper slopes of a limestone ridge. The ore occurs mostly in fragments on the surface, covering probably about seven acres, and is mixed with

The Deadrick tract.

angular fragments of gray or rusty brown chert. In some places, however, where it is exposed in place, its original mode of occurrence is found to be as masses and pockets in the chert, sometimes also as the cement of a chert breccia. Near the base of the deposit the ore becomes more and more cherty until it is finally cut out altogether by solid chert, and this rock in turn is soon replaced by the underlying limestones. The ore represents an irregular and isolated body in the chert, probably not more than twenty feet thick anywhere and much thinner in some places, while the chert itself represents an irregular bed in the upper part of the limestone.

ore is quite erty.

The following analysis by A. E. Menke shows the composition of the iron ore from this property: —

ysis of the

ANALYSIS OF IRON ORE FROM THE DEADRICK TRACT, FULTON COUNTY.

Iron	44.97
Silica	21.40
Phosphorus	0.031
Sulphur	0.109
Manganese	none.

The analysis shows the ore to be high in silica, though some of the ore on this tract is of better quality than that represented by the analysis.

RANDOLPH COUNTY.

General Features. Iron ores in the form of brown hematite occur in many parts of Randolph county, especially in the county between Spring river and Eleven Points river, and also in the northeastern part of the county near the Arkansas and Missouri boundary line, but so far as yet discovered the deposits are all too small and often too poor in quality to be of any commercial value.

Ravenden Springs. The village of Ravenden Springs is in 19 N., 2 W., section 7. Though no iron ore occurs in the immediate neighborhood of the village, it is found in several places at short distances to the east and south, on the divide between Spring river and Eleven Points river. The main part of this

divide in the region in question is a long tortuous ridge running in a general northwest and southeast direction and rising from 200 to 300 feet or more above the surrounding drainage. The lower part of the ridge, for sometimes 200 feet from the base, is composed of the blue limestone already described (page 23). The rock becomes cherty towards the top, and the upper part of the bed is composed largely of chert for a thickness of probably, in some places, 75 feet or more. The chert usually forms the crest of the ridge, giving it the rough rocky appearance of a chert region. On the higher parts of the ridge, however, the sandstone, which belongs above the chert, often appears and forms the summit. Occasionally the chert is absent and the sandstone and limestone come into direct contact, as already explained on page 23. Most of the iron ore occurs on the summit of the ridge, as pockets in the chert, the deposits forming, on account of their dark color, a striking contrast with the light gray chert which surrounds them on all sides. Chert on the hills.

About a mile and a half east of Ravenden Springs a small pit has been made in a deposit of brown hematite. The chert has partly decayed and the ore occurs in masses and layers in a brown and white clay which has resulted from this decomposition.

The following analysis by A. E. Menke shows the composition of this ore:—

ANALYSIS OF IRON ORE FROM NEAR RAVENDEN SPRINGS, RANDOLPH COUNTY. Analysis of the ore.

Iron	50.49
Silica	12.60
Phosphorus	00.14
Sulphur	0.102
Manganese	a little.

The analysis shows an ore of fairly good quality. The quantity of the ore, however, is uncertain, as very little prospecting has been done, but it is probably limited.

Southeast of this locality, for five or six miles along the crest of the ridge, similar or even smaller deposits occur. Sometimes they show small quantities of ore, at other times they are simply rusty chert.

Jackson. The old village of Jackson is about eight miles southeast of Ravenden Springs and on the divide between Spring river and Eleven Points river, already described. Less than a mile north of the village and in 17 N., 1 W., section 2, on the old military road, a few scattered lumps of brown hematite, associated with fragments of chert, occur on the upper slopes of a hill. The ore is in very small quantities.

The Odom tract.

The B. B. Odom Tract. The Odom tract is in 18 N., 1 W., section 18, the northeast quarter of the northeast quarter. Masses of iron ore associated with fragments of chert occur here, but the deposit has not been prospected and is so covered with soil that it is difficult to determine anything about its extent. Some of the ore contains rounded siliceous pebbles, and occasionally it forms the cement of a mass of pebbles and sand. Such materials may possibly represent a later formation than the other ore and, if so, the iron in them has probably been derived from the older ore.

The following analysis by A. E. Menke shows the composition of the ore: —

Analysis of the ore.

ANALYSIS OF ORE FROM THE ODOM TRACT, RANDOLPH COUNTY.

Iron	44.44
Silica	11.83
Phosphorus	0.021
Sulphur	0.157
Manganese	a little.

The analysis shows the ore to be somewhat low in iron but good in other respects.

Iron ore somewhat similar to that on the Odom tract also occurs in 18 N., 1 W., section 6, the west half of the southwest quarter.

Iron Bank. What is locally known as Iron bank is in 21 N., 3 W., section 8, the northwest quarter of the southwest quarter, about a quarter of a mile south of the Arkansas and Missouri boundary line and about fifteen miles east of the town of Mammoth Spring. The ore is a brown hematite and occurs in association with chert on the end of a ridge. The lower part of the ridge is composed of the blue limestone, and the chert occurs with a

thickness of about thirty feet on the summit. The fragments of ore cover about five acres on the top of the ridge and the deposit represents a local body of ore in the chert. Occasionally the ore forms the cement of a chert breccia.

The following analysis by A. E. Menke shows the composition of the ore from this property :— Analysis of ore from Iron Bank.

ANALYSIS OF IRON ORE FROM IRON BANK, RANDOLPH COUNTY.

Iron	49.97
Silica	14.53
Phosphorus	0.014
Sulphur	0.082
Manganese	trace.

The analysis shows the ore to be fairly good in its percentage of iron but somewhat high in its percentage of silica.

APPENDIX B.

HISTORICAL AND STATISTICAL SKETCH OF THE IRON INDUSTRY OF MISSOURI.

BY ARTHUR WINSLOW,

ASSISTED BY

C. F. MARBUT.

INTRODUCTION.

Early Discovery in America. The first discovery of iron ore in the United States is credited to the year 1585, to an expedition fitted out by Sir Walter Raleigh and commanded by Ralph Lane.[1] The discovery was made along the Roanoke river. No attempt was made to utilize the iron, however, as the explorers were in search of gold and not iron. Iron ore was discovered soon afterwards in Virginia and early in the 17th century attempts at its manufacture were begun. From this time on the discovery of other deposits of iron ore and the development of the iron industry in the eastern States steadily progressed.

Iron discovered in America in the sixteenth century.

First Discovery in Missouri. The exact date of the discovery of iron ore in Missouri we are unable to state. With our knowledge that the lead ores of the State were probably known to and operated by the French as early as the year 1700, it is probable that the existence of iron ore was also known as early as that time. Not until after the year 1815 have we, however, any record of these ores being utilized. By this time a very considerable iron industry had developed in the eastern States. Iron works were in operation in Massachusetts, New York, New Jersey, Maryland, Virginia, in Pennsylvania and in Ohio. West of Ohio, however, with the exception of a nailery established in

Probably known to the French in 1700 in Missouri.

[1] James M. Swank, History of the Manufacture of Iron in All Ages, p. 102.

Indiana Territory,[1] no iron industry was begun. The development of the iron mines of Michigan and Wisconsin was of later date. Missouri can, hence, probably claim the distinction of being the first State west of Ohio to start the manufacture and smelting of iron ore. The prominence of its position in the Mississippi valley and the reputation which it had enjoyed abroad as a mineral producing area had attracted many men interested in mining to within its borders. These are facts which led to the early development of the lead mines and they doubtless had influence in starting the early iron industry.

Missouri's prominence as a mineral-producing area.

In the following pages we shall attempt to describe the growth of this industry and to accompany such description by all the statistics that we have been able to obtain. For ready comparison with the chapters of the preceding report, we shall discuss the different classes of ore separately. (1) Specular Ores in Porphyry, (2) Red Hematites, (3) Specular Ores of the Sandstone Region, (4) the Limonite Ores. Under these headings, we will note the inception of mining at the principal iron mines in the State, and will, at the same time, refer to the manufacture of iron at each of these localities. The summaries of production are tabulated after this systematic description and a special section at the end describes the Metallurgy of Iron in the State.

The beginnings of iron mining in the State.

IRON MINING.

SPECULAR ORES IN PORPHYRY.

Ashebran's Furnace. The specular ores in porphyry were the first ores to be mined and smelted in the State. According to Swank,[2] from information furnished him by Mr. W. A. Fletcher of Ironton and Mr. A. W. Holloman of Arcadia, what is known as Ashebran's furnace, which was erected about 1815 or 1816, was the first iron enterprise in the State. It was located at the Shut-In, about two miles east of Ironton. Swallow[3] states that "one of the first iron furnaces in this part of the country was erected at this place;" but he does not give the date of its erec-

The earliest attempt at iron smelting in 1815.

[1] Swank, Opus Cite, p. 314.

[2] Opus Cite, p. 332.

[3] Report Mo. Geol. Survey, 1855, Part I, p. 155.

…port, bar iron was made at this place, the …d by a big shaft and a water wheel. The …s obtained from Shepherd mountain. Just … furnace continued in operation we do not …robable that it was active for a number of

The next enterprise connected with these …at the well-known Iron mountain. According … attention of some Missouri capitalists was … deposits in the year 1836, and in the fall of …ssouri Iron Co., with the nominal capital of … formed and chartered. According to notes … by Prof. Wm. B. Potter, mining engineer of …on Mountain Mining Co., "Iron Mountain is …ld Spanish grant of 20,000 arpents (17,013.88 …ph Pratte. This was confirmed by the United …s July 4, 1836. In 1840 a schoolmaster by the …Dora secured an option on the property and went to …to organize a company. He failed in this and soon …American Iron Mountain Co. was incorporated Jan…43. June 9, 1845, Conrad C. Ziegler and Elvina, …eded 11/14th parts 'of a tract of land situated on the …s of the St. Francois river in the counties of St. …nd Washington in the State of Missouri, containing …ents, more or less, known as the Iron Mountain tract, … Iron Mountain, etc.' On the same date James Harri… Maria L., his wife, deeded the other 3/14ths also to the …n Iron Mountain Co. Mining began in 1844 on surface …. On May 10, 1869, the present Iron Mountain Co. …anized. The first ore treated at Iron Mountain was in …, 1846, when furnace No. 1 was put in blast. In January, … No. 2 furnace was put in blast. In 1851 Valle Forge was …between Farmington and Ste. Genevieve and continued in …tion until 1866, making iron blooms from Iron mountain … which latter was hauled to the forge, the blooms being …ed from there to the river at Ste. Genevieve. In January,

Iron Mountain an old Spanish grant.

Formation of the present Iron Mountain Co.

…Opus Cite, p. 335.

1855, No. 3 furnace was put in blast. In 1858 the Iron Mountain R. R. was built as far as Pilot Knob and soon after shipments of ore began from Iron Mountain to Irondale and to a small iron furnace at Carondelet. The last iron made at Iron mountain was in 1877 and the total amount of pig iron made there was 192,731 tons. The whole amount of ore mined at Iron mountain is approximately 3,360,000 tons of 2240 lbs. up to January 1, 1892."[1]

Total yield of Iron Mountain 3,360,000 tons.

The following table, kindly furnished by Mr. John Birkenbine, special agent in charge of the collection of iron statistics for the Eleventh Census and for the U. S. Geological Survey, gives the total amount of iron ore shipped during the successive years of mining, from 1870 to 1887, inclusive. The books of the company were destroyed by fire in 1870 and, hence, earlier details are not procurable. The figures given for 1890, 1891 and 1892, are from the reports of Mr. C. C. Woodson, the State mine inspector for the respective years; they represent *productions*, not *shipments*.

SHIPMENTS OF IRON ORE FROM IRON MOUNTAIN.[2]

Shipments of ore from Iron Mountains.

Year	Gross Tons.	Year	Gross Tons.	Aver. value.
Prior to and including 1870	791,077	1882	62,043	
1871	157,904	1883	51,352	
1872	269,480	1884	47,220	
1873	235,130	1885	52,993	
1874	103,680	1886	138,082	
1875	107,220	1887	113,589	
1876	107,430	1888	2,736,445	
1877	75,468	1889		
1878	95,930	1890	85,268[3]	$3 41
1879	142,368	1891	66,914[3]	2 62
1880	108,045	1892	78,969[3]	1 79
1881	77,434			

Total amount produced (mined) up to the end of the year 1891...3,349,086 tons.

[1] According to figures furnished by Mr. John Birkenbine, and presumably derived from the same source, the total amount of iron ore produced up to the end of 1891, is 3,349,086 long tons, a difference of about 11,000 tons.

[2] Figures for the years 1870 to 1887, inclusive, are of *shipments* and do not indicate stock ore.

[3] Figures for 1890, 1891 and 1892 are of amounts *mined* and they also apply for the year ending June 30th.

Pilot Knob, according to notes also furnished by Prof. Potter "was first entered in 1835." "Pratt and Valle soon after came into possession but it was not till 1847 that much work was done. The Madison Iron Mining Co., with Bernard Pratte, President, and Conrad C. Ziegler, Manager, was organized in 1848, and a furnace built. The first mining also commenced at this time. In 1853 the second furnace was built. About this time the company was reorganized as the Pilot Knob Iron Co. In 1882 the property was consolidated with the Vulcan Iron and Steel Works and the Grand Tower Coal Co., forming the St. Louis Ore and Steel Co. The total amount of ore mined at Pilot Knob is about 1,500,000 tons, besides which Shepherd Mountain has yielded about 75,000 tons, Cedar Mt. about 25,000 tons, Buford Mt. about 3,000 tons, Russell Mt. about 3,000 tons and the Shut-In about 600 tons. All of the last named places belong also to the Pilot Knob property." Madison Iron Mining Co. organized in 1849.

The following table, kindly furnished by Mr. E. A. Hitchcock, president of the St. Louis Ore and Steel Co., gives the annual output of the mine during the years 1882, to 1892, inclusive. The records of operations prior to 1882, Mr. Hitchcock is informed, were destroyed by fire. Early records of the Pilot Knob Co. destroyed by fire.

ANNUAL PRODUCTIONS OF PILOT KNOB MINE.

	Gross Tons.		Gross Tons.
1882	90,477	1888	98,298
1883	116,699	1889	57,630
1884	124,636	1890	33,819
1885	136,737	1891	5,852
1886	198,909	8 mos. of 1892	4,942
1887	206,273		
Total from 1882 to 1892, inclusive			1,074,272

Annual production of Pilot Knob mine.

The figures of the State mine inspector for recent years are as follows, the year in each case ending June 30th:

	Gross Tons.	Aver. Value.
1890	59,731	$1 45
1891	14,830	1 60
1892	7,049	2 07

As referred to in connection with Pilot Knob, iron was mined

not only from Iron mountain and Pilot Knob themselves, but also from Buford mountain, about three miles west of Iron mountain, and from Shepherd mountain, Cedar mountain and Russell mountain in the vicinity of Pilot Knob.

Iron mined from several deposits near Pilot Knob

The furnaces used at both mines were charcoal furnaces, the charcoal being burned in the neighborhood.

Decline of Production. Operations at both of these mines were practically continuous from the time of their beginning up to the present date, though the amounts produced have fluctuated considerably. The past twenty years has been the period of greatest activity; in fact, as the tables show, fully 66 per cent. of the ore produced at the Iron mountain mine has been mined during the past twenty years and 66 per cent. of that produced by the Pilot Knob mine has been mined during the past ten years. Both mines show a noticeable decrease in the amounts produced during recent years. The maximum annual production of the Iron Mountain mine was 269,480 tons in the year 1872. The production for the year 1892 was only about thirty per cent. of this. The maximum production of the Pilot Knob mine was 206,273 during the year 1887. The present production is about three per cent of this.

Production of Iron Mountain and Pilot Knob declining.

The reasons for the reduction in the amounts of ore produced, as has been explained in the chapters of the preceding report, is principally on account of the diminution of the known supply of ore, though the conditions of the market have also had their influence. The prospects of further discovery of ore have already been stated, and need not be repeated here; that the conditions of the market will always permit of the profitable sale of such excellent ores as these, if they can be mined at reasonable cost, cannot be doubted.

Values of Ores. Concerning the values at the mines of these ores we have not been able to obtain much information. Large orders are reported to have been filled at Iron mountain between the years 1870 and 1880 at a rate of $10.00 per ton and one large order gave nearly $15.00 per ton. For the years 1882 to 1892 we have been furnished with the following rates, at which large lots of these porpyhry ores were sold. We are not at liberty to state which mine the ore was obtained from, but it can

Ores brought high prices.

be applied, for general comparative purposes at least, to either mine.

VALUES OF SPECULAR ORES IN PORPHYRY.

1882	$4 17	1888	$2.87
1883	3 64	1889	2.15
1884	4 06	1890	2.09
1885	3 01	1891	2.34
1886	2 87	8 mos. of 1892	2.17
1887	3 04		——
Average, 1882 to 1892			$3.17

Values of specular ore.

THE RED HEMATITES.

The red hematites, as defined in the preceding report, are found principally in Lincoln and Callaway counties, in Benton, Henry and St. Clair counties, along the upper waters of the Osage river, and occasional unimportant occurrences have been noted in a few other counties. Nothing that can be dignified with the term of mining operation has been conducted in these ores. The most considerable deposits so far found are in Lincoln and Callaway counties; but little more than prospecting has been done in any of the deposits there recognized. This has been done at irregular intervals during the past twenty years. The amount of ore mined from all probably does not exceed a few hundred tons. Whatever the value of these deposits may be determined to be in the future, the extent of their development up to the present time is not sufficient for them to receive further consideration here.

No mining done in these ore fields.

THE SPECULAR ORES OF THE SANDSTONE REGION.

The specular ores of the sandstone region rank next in importance to those associated with the Archean porphyries. It is of these also that we have the second earliest record of iron ore being mined and worked in the State.

The Harrison-Reeves Bloomary is the operation referred to; it was located on Thicketty creek, a tributary of the Meramec river in Crawford county, near the Washington county line, three miles south of the town of Bourbon. Cresswell's mill was afterwards built about one hundred yards from the site of

Early bloomary furnaces established.

this early iron enterprise.[1] The works were built during 1819 and 1820, and were rudely constructed of logs and rocks, being simply a stone stack built into a hill. The iron was made into long bars, the bloom of iron being hammered under a spring-pole hammer on an anvil. The ore was brown hematite mixed with blue specular ore and was hauled in ox carts from the adjacent hills.

Bloomary rudely built.

The Eversol, Perry and Ruggles Furnace was the next enterprise of which we have any record. It was located between Potosi and Caledonia. This furnace Dr. Litton[2] characterizes as the "earliest attempt in Missouri, and, in all probability, in any of the States west of Ohio, to smelt iron ore." This furnace was also known as the Springfield furnace and is so described by Swank.[3] Cannon balls are reported to have been made for the general government at this furnace in 1832. It was at one time known as Perry's Old Iron Furnace. Litton states that the ore first used was obtained from Clear creek; afterwards four-fifths of that smelted came from Absalom Eaton's place and was mixed with ore brought from Iron mountain. The ore near Mr. Eaton's is a brown hematite. Dr. Litton further quotes Col. McIlvane to the effect that the first bar of iron made out of pig metal in Missouri was mined in Cedar creek in May, 1825, and the first blooms were made in 1832.

Cannon balls for the army made here.

The Meramec Ore Bank, in Phelps county, about five miles southeast of St. James, is one of the oldest mines operated in the State. According to Dr. B. F. Shumard[4] it was opened as early as the year 1826 by Messrs. Massey and James, who commenced the erection of the furnace, which was completed in the month of January, 1829, and was in operation at intervals during the next thirty years. The ore is a rich, compact, specular hematite. This mine was in operation during the year 1891 and has been an ore-producer intermittingly from its beginning to this date. According to *Campbell's Gazetteer*, p. 434, it was in operation in the year 1873, and according to the Mine Inspector's

Ore of excellent quality.

[1] Swank, Iron in All Ages, p. 333.
[2] Report of Missouri Geol. Survey, 1855, Part II., p. 73.
[3] Opus Cite, p. 334.
[4] Report Missouri Geol. Survey, 1855 to 1871, p. 238.

report was in operation in the years 1890 and 1891. The books of the company have been destroyed by fire and hence detailed figures of the production of this mine are not obtainable. The Mine Inspector's report for 1891 puts the production at 2302 tons at $2.80 per ton. According to the figures kindly furnished by Mr. Wm. James of St. James, the total production of this mine up to the end of the year 1891 is 375,000 tons.

The Scotia Iron Furnace, in Crawford county, about eight miles southeast of Leasburg, was erected in 1849. The ore used was from the Scotia mines at the same locality and is a hard specular hematite. Two mines were opened in close proximity to each other (about three miles apart), known respectively as Scotia No. 1 and Scotia No. 2. These mines we find referred to in *Campbell's Gazetteer* as operating in the year 1873. We have not the data from which to state during what years these mines were in operation nor the amounts produced during the different years. The furnace was subsequently moved to a point further south in Dent county and was then known as the Nova Scotia furnace. This went out of blast about the year 1884 and has since been moved to Paducah, Ky. The total production of the Scotia No. 2 mine, according to the figures furnished by Mr. Wm. James, is 7000 tons; Scotia No. 1, according to Mr. Scott, former owner of the mine, produced 150,000 tons; Mr. James further adds that the total amount of ore smelted at the Old Scotia furnace was 290,000 tons.

Two mines operated.

Blast furnace removed to Paducah, Ky.

The Old Franklin or Moselle Furnace, in Franklin county, near Moselle, was built in the year 1857.[1] It is referred to by Litton in 1855.[2] The ore used at the time of Dr. Litton's visit was from a deposit near by of red hematite; later the ore from Benton Creek mine, in Crawford county, was used.

From this date on up to 1870, we have been able to collect no notes of importance relating to the mining of these ores. In fact, previous to that year most of the iron mining of the State was at the Iron mountain and Pilot Knob mines, and at the localities in Phelps, Crawford, and Franklin counties already described.

[1] Report Mo. Geol. Survey, by Chas. P. Williams, 1877, p. 142.
[2] Report Mo. Geol. Survey, 1855, Part II, p. 74.

The Hamilton Iron Works, in the northwestern corner of Washington county, were built in the year 1873, and more or less iron mining in the surrounding country must have been prosecuted to supply these works.

melting in ...hington Co

The Benton Creek Mine, on Benton creek in the southwestern corner of Crawford county, was opened in the year 1873. The ore was partly specular and partly limonite. It was operated during the years 1873, 1874, 1882, 1886 and 1887. The amount of ore mined during each of these years is given in the following table, kindly furnished by Mr. T. T. Lewis, secretary of the Meramec Iron Co.

IRON ORE PRODUCED AND SHIPPED TO DATE AT THE BENTON CREEK MINE.

	Gross Tons.
1873	25,313.32
1874	18,863.84
1882	894.00
1886	348.00
1887	2,114.36
Total	47,533.52

Since 1887 no work has been done at the mine, to the writer's knowledge.

The Steelville Iron Mines, about three miles southwest of Steelville, were first operated in 1873 and 1874 and again in 1880 to 1881. The exact amounts produced during these periods could not be obtained, but Judge A. J. Seay of Oklahoma Territory, informs us that, in his estimation, these mines yielded from 5000 to 6000 tons.

...ille mines ...ded about ... tons.

According to the notes in *Campbell's Gazetteer*, the Grover, Benton Creek and Iron Ridge mines being operated in Crawford county in the year 1873, and the Buckland and Beaver Creek mines in Phelps county during the same year.

The Simmons Mountain Mine is one of the largest operated in the region. It is situated about two miles southwest of Salem. The ore is mostly specular hematite. According to the Mine Inspector's reports for the years 1889, 1890, 1891 and

1892,[1] this mine was in operation during this period, and the following amounts are stated to have been produced:—

	Tons Produced.	Value Per Ton.
1890	6,911	$2 37
1891	4,472	2 25
1892	7,454	1 60

Values of Simmons Mountain ores.

According to figures kindly furnished by Mr. E. B. Sankey of Salem, the total amount of ore produced at this mine up to the end of the year 1890 was 234,114 tons.

The Ozark Furnace, in Phelps county, near Newburg, was built in 1874.[2] It used ores from the Beaver mine in Phelps county, about five miles southwest of Rolla; from the Hancock mine in Miller county, about three miles northwest of Hancock in Pulaski county, and from the St. James mine near St. James, in Phelps county.

The Midland Furnace, in Crawford county, about a mile north of Steelville was put in blast in 1875. The ore was used from the Ferguson mine at Salem in Dent county and from other mines in Dent and Crawford counties; but the largest source of supply has been the Cherry Valley mine.

The Cherry Valley Mines are in Crawford county, about six miles east of Steelville. They are the largest mines of the kind in the State and have been the largest ore-producers outside of Iron mountain and Pilot Knob. The mines are connected with the Midland furnace by a narrow-gauge railway. The ore is principally specular hematite. A full description of the ore and of the deposits is contained in the preceding report and nothing further need be said here. The total amount produced at this mine up to the middle of the year 1892, is 490,813 tons.

One of the largest iron mines in the State.

The following table, courteously furnished by Mr. T. T. Lewis, secretary of the Meramec Iron Co., gives the amount of ore produced by the mine during its years of operations and also the average price per ton during each year. This price is made

[1] Year ending July 30th.

[2] Report Mo. Geol. Survey, 1877, p. 134.

to cover the cost of hauling the ore from the mine to the Midland furnace, which is charged to the expenses of mining.

From this table it will be seen that the mine has been continuously in operation from the time of beginning to the current year.

IRON ORE SHIPPED FROM CHERRY VALLEY MINE AND VALUE PER TON.

Year.	No. Tons Sold. Gross Ton.	Average Price Per Ton at Midland, Mo.
1878	6,722	$4 06
1879	43,991	2 21
1880	53,448	2 78
1881	22,195	5 24
1882	31,847	5 19
1883	15,132	2 83
1884	13,680	1 95
1885	21,436	1 96
1886	24,515	2 19
1887	74,545	2 23
1888	45,462	2 18
1889	51,078	2 27
1890	64,476	2 29
1891	16,472	2 51
1892 for 6 months	5,744	2 67
Total	490,713 Average,	$2 84

The Hawkin's Mine, at Condray, in Dent county, was opened in the year 1879,[1] and has been operated at intervals since. According to figures furnished by Mr. Condray, the superintendent, the production from January, 1891, to August 31, 1892, was 32,484 tons.

According to the mine inspector's figures the following prices prevailed: —

	Price Per Ton.
1890	$2 00
1891	2 25
1892	1 75

According to figures kindly furnished by Mr. E. B. Sankey the total amount of ore produced up to and including the year

[1] Mine Inspector's Report for 1891, p. 190.

1890 was 83,000 tons, which will make the total to date about 120,000 tons; only about half of this has been marketed.

The Coons' Mine, in Franklin county, according to information kindly furnished by Mr. J. L. Buskett of Rolla, was begun in the fall of 1880 by John W. and J. L. Buskett, and work was continued for about two years, and was subsequenly worked by Mr. H. A. Hibbard of St. Clair. The Buskett brothers mined and shipped about 5000 tons which they sold in St. Louis at from $6.00 to $7.50 delivered in St. Louis, freight on the same being $1.75 per ton. Coons' mine worked intermittently.

The Letcher Mine was opened in 1881, and was worked by Wm. C. and J. L. Buskett until December of the same year, when they sold their lease to the Missouri Furnace Company of St. Louis. During the period that Wm. C. and J. L. Buskett worked the Letcher mine they shipped about 3000 tons of ore, 1000 of which went to Wheeling and the balance to St. Louis at the same prices quoted above. The Missouri Furnace Company, Mr. Buskett says he has been informed, shipped about 5000 tons of ore from the mine and then abandoned it on account of water. Ore shipped to Wheeling.

LIMONITE ORES.

Concerning the mining of limonite ores in the State little can be said, for the reason that very little of this ore has been produced up to the present date. About the earliest reference which we have to the mining of such ore is in connection with the Osage Iron Works, near the Osage river, about fifteen miles above Linn creek. According to information kindly furnished by Gov. J. W. McClurg, this furnace was erected about 1873 or 1874, and was operated three or four years; it was then abandoned on account of the fact that no bodies of ore were found sufficient to supply the furnace. The ore used was brown hematite or limonite and was found in small quantities within a radius of about eight miles from the furnace. Mr. McClurg is of the opinion that not as much as three hundred tons of pig iron were produced. Osage Iron W[orks] failed.

The Limonites of Southeastern Missouri, described by Mr. Moore in the report of the Geological Survey of 1873–4, were

apparently prospected to a certain extent about that time, but probably little or no ore has been shipped. We have been unable, so far, to obtain anything more than a few figures concerning the production since that time.

Madison County ore used mainly as flux for lead smelting.

In Madison County are several small, scattered deposits of limonite ore which have supplied the lead furnaces of the vicinity. Most of the product has gone to Mine La Motte, and concerning this Mr. J. D. Sanders, the superintendent, writes as follows: "From 1884 to 1890, most of it was obtained from deposits on the Mine La Motte tract. In 1890 we got 314 tons from the Mine La Motte tract and 145 tons from the Cornwall mines and vicinity, about 5 miles S. E. of Fredericktown on the Iron Mountain Ry. In 1891 we bought 800 tons of ore, mostly from the Cornwall mines and immediate vicinity. In 1892, up to Nov. 15, we have bought 333 tons of ore, mostly from the vicinity of the Cornwall mine. Since about 1884, we have used about 600 tons of limonite ore annually, nearly all of which has been obtained from various deposits in Madison Co."

St. Francois Co. ore, ditto.

In St. Francois County small amounts of limonite have been mined to supply the lead furnaces at Bonne Terre. Mr. Gust. Setz, assistant superintendent of the St. Joe Lead Company, informs us that about 300 tons have been obtained from the vicinity of Bismark and about 200 tons from other points in the county.

Wayne Co. ore, ditto.

In Wayne County, the Cedar Bay mines, about three miles northeast of Leeper, were opened in 1883, and were last worked in 1888. Previous to 1884 several car loads of ore from these mines were shipped to Mine La Motte, by Mr. C. D. Yancey of Piedmont, and about 500 tons to Bonne Terre. Mr. J. L. Clarkson of Cedar Bay reports that about five thousand car loads (one hundred thousand tons, about) were shipped from these mines in all. It seems hardly probable, however, that so large an amount has been produced at these mines. Mines situated near this, in sections 18 and 19, T. 28 N., 4 E., shipped fifteen carloads (three hundred tons) of limonite about the year 1884, according to Capt. Leeper.

In Butler County a mine a mile or two east of Hendrickson, was described in the report of 1872–4. A good deal of excavat-

ing has been done here and probably some ore was shipped, but we have been unable to determine the amount.

In Oregon County are several deposits of limonite which have been prospected and from which small quantities of ore have been taken. The T. J. Boyd bank, near Thayer, in section 29, T. 22 N., 5 W. is such a one. The ore was shipped in 1887, but we do not know the amount. The Old's bank, four miles west of Thomasville, is another point where some prospecting has been done. Several small producers in Oregon Co.

In Howell County is the largest deposit of limonite which has been operated during recent years. This is the Lamons mine, three miles northward from West Plains. Work was begun here in the year 1889 and has continued up to the present date. The total amount shipped at the end of the year 1892 is about ten thousand tons.

PRODUCTIONS OF IRON ORES TO DATE.

In the preceding pages we have given, in chronological order, under the heading of the different classes of ores, brief notices of the inception and progress of iron mining of different localities. To these notices we have added such details of annual production and prices of ores at different mines as we have been able to obtain. Concerning the most important mines we have been so fortunate as to obtain the data in considerable detail; but concerning by far the greater number of the smaller mines we have been able to obtain very little. Through the courtesies of various gentlemen whose names are given below we have secured however, the total production to date of most of these mines. These results are imbodied in the following tables. Concerning those mines of which we could not get figures of productions, but which we know to have been operated, estimated amounts are inserted in the table and also for the productions of the latter half of the year 1892. The mines are grouped by counties and the counties are given in alphabetical order. The greater part of the material of these tables has been collected by Mr. C. F. Marbut through correspondence and interview. Here, as else- Data concerning small mines incomplete.

where in this report, the tons given are assumed to be gross tons, of 2240 pounds, unless otherwise stated.

TABLES OF TOTAL PRODUCTIONS OF INDIVIDUAL IRON MINES IN MISSOURI UP TO THE END OF 1892.[1]

ty for fig- iven.

In the following tables the sources of the information in different cases are indicated as follows: Mr. William James by (J.); Mr. E. B. Sankey by (S.); Mr. Green by (G.); Mr. W. A. Dorey by (D.); Judge A. J. Seay by (Se.); Mr. T. T. Lewis by (L.); Mr. William Kelly by (K.) Mr. J. D. Sanders by (Sa.); Prof. Wm B. Potter by (P.); Mr. E. A. Hitchcock by (H.); Mr. J. L. Buskett by (B.); Mr. C. C. Woodson by (Wo.); Mr. Scott by (Sc.).

CRAWFORD COUNTY.

Name.	Location.	Production. Gross Tons.
Benton Cr. mine (L.)	Sec. 32, T. 36 N., 5 W.	47,533
Bonito mine (S.)	Sec. 12, T. 36 N., 5 W.	841
Bower's mine		1,000
Buffum mine (S.)	Sec. 32, T. 37 N., 4 W.	10
Card, J. P. (G.)		3,000
Cherry Valley mine (L.)	Sec. 4, T. 37 N., 3 W.	497,563[2]
Craig mine (S.)	Sec. 24, T. 36 N., 5 W.	10,398[2]
Deffebach mine (G.)		250
Grover-Ferguson mine (S.)	Sec. 21, T. 37 N., 4 W.	2,570
Haney mine (S.)		4,195
Hart mine (S.)	Sec. 24, T. 36 N., 5 W.	780
Iron Ridge mine No. 1 (D.)	Sec. 29. T. 39 N., 5 W.	180,841
James mine (at Wilson's Mill) (J.)	Sec. 12, T. 36 N., 5 W. (?)	2,100
Keyes		500
Pinnel mine (G.)		550
Pease mine (S.)	Sec. 12, T. 36 N., 5 W.	1,251
Scotia mine No. 1 (Sc.)	Sec. 1, T. 38 N., 3 W.	150,000

[1] The diagram of the State on the opposite page is introduced here to accompany these tables. The circles indicate the counties in which iron ore is known to occur in the State; the black bars indicate those counties which have been iron ore producers in the past, the length of the bar being proportional to the amount produced to date; the black squares show the counties which have been producers during the year 1892, the size of the square being proportional to the amount produced during that year.

[2] Last half of 1892 estimated.

Scotia mine No. 2 (J.)	Sec. 28, T. 39 N., 2 W.	7,000
Seay mine (S.)	Sec. 5, T. 37 N., 4 W.	3,722
Steelville mines Nos. 1 and 2 (Se.)	Sec. 5, T. 37 N., 4 W.	5,500
Taylor mine (J.)	Near Jakes Prairie	2,500
Varris and Arnold mine (G.)		550
Other small mines (D.)		5,500
Estimated production from other banks including the Reuben Smith, New York, Rowden, Watros, Thompson, Wilkerson, Bleeding Hill, Clark & Co., N. G. Nos. 1 and 2, Knox, Cook, C. C., Arthur-Revold, Key, Anderson, Dry Creek Carson, and Red Hill banks		140,000
Total		$1,068,154

DENT COUNTY.

Name	Location	Production. Gross Tons.
Arnold mine (S.)	Sec. 9, T. 35 N., 5 W.	125
Causey mine (S.)		100
Clark-Taylor mine (S.)	Sec. 12, T. 34 N., 7 W.	16,827
Dry Fork mine (S.)		13,121
Ferguson mine (S.)	Sec. 13, T. 34 N., 6 W.	43,500
Fitzwater mine (S.)	Sec. 15, T. 34 N., 4 W.	6,000
Gearhart mine (S.)		1,000
Graff-Blackwell mine (S.)	Sec. 12, T. 35 N., 6 W.	48 [1]
Hawkins mine (S.)	Sec. 11, T. 35 N., 6 W.	121,979
Hayes mine (S.)	Sec. 20, T, 34 N., 5 W.	5,000
Hutchens Creek mine (S.)	Sec. 15, T. 34 N., 4 W.	2,008 [2]
Huzzah Howe's mill, mine (S.)	Sec. 9, T. 34 N., 3 W.	1,000
James mine (S.)		79
Jamison mine (S.)	Sec. 1, T. 33 N., 6 W.	22,354
Kerr mine (S.)		168
Norris mine (S.)	Sec. 12, T. 34 N., 5 W.	1,300
Nova Scotia, Barksdale mine (S.)	Near Nova Scotia Furnace	27,500
Orchard mine (S.)	Sec. 13, T. 34 N., 6 W.	41,654
Orchard and Young, Thorpe, Preston or Pittsburg mine (S.)	Sec. 27, T. 34 N., 6 W.	15,000
Plank mine (S.)	Sec. 33, T. 35 N., 6 W.	{ 10,000 [1] 49,214

[1] Last half of 1892 estimated.

[2] Mr. Sankey thinks this amount represents only the shipments by rail. The mine was worked for some time by the Sligo Furnace Co. and the ore was hauled in wagons to the furnace.

Pomeroy mine (S.)	Sec. 10 T. 34 N., 6 W.	35,400
Red Mountain mine (S.)	Near Nova Scotia Furnace	27,300
Riverside-Ziegler mine (S.)	Sec. 2, T. 33 N., 5 W.	45,000
Simmons Mountain mine (S.)	Sec. 24, T. 34 N., 5 W.	13,176[1] / 234,114
Thomas mine (S.)	Sec. 17, T. 34 N., 6 W.	6,320
Watkins mine (S.)		1,930
Williams mine (S.)	Sec. 16, T. 35 N., 6 W.	1,410
Estimated production of other mines including Merriam and Slater mines		6,000
Total		748,827

FRANKLIN COUNTY.

Name.	Location.	Production. Gross Tons.
Booth mine (B.)		10,000
Coons mine (B.)		5,500
Iron Hill mine (B.)	Sec. 17, T. 41 N., 1 W.	5,000
Judith Springs mine (B.)		30,000
Letcher mine (B.)		8,000
Reed Copper mine (B.)		5,000 partial.
Spring Creek mine (B.)		2,000
Surface ore from several places (B.)		3,800
From Dry Branch 1892		400[1]
Total		69,700

HOWELL COUNTY.

Name.	Location.	Production. Gross Tons.
Lamons mine	Sec. 35, T. 24 N., 8 W.	10,000

IRON COUNTY.

Name.	Location.	Production. Gross Tons.
Pilot Knob mine (H.)	Sec. 29, T. 34 N., 4 E.	1,578,272[1]
Shepherd Mountain mine (P.)	Sec. 31, T. 34 N., 4 E.	75,000
Cedar Hill mine (P.)	Sec. 30, T. 34 N., 4 E.	25,000
Buford Mountain mine (P.)	Sec. 26, T. 35 N., 3 E.	3,000
Russell Mountain mine (P.)	Sec. 13, T. 33 N., 3 E. (?)	3,000
The Shut-In mine (P.)	Sec. 3, T. 33 N., 4 E.	600
Total		1,684,872

[1] Last half of 1892 estimated.

MADISON COUNTY.

Name.	Location.	Production. Gross Tons.
Cornwall and Mine La Motte tract, and Vicinity (Sa.)		5,000[1]
Estimated production from the same place shipped to the Irondale furnace in Washington County		5,000
Total		10,000

PHELPS COUNTY.

Name.	Location.	Production. Gross Tons.
African mine (S.)	Sec. 27, T. 36 N., 6 W	1,658
Beaver Creek mine (J.)	Sec. 33, T. 37 N., 8 W	49,000
Buckland mine (K.)	Sec. 20, T. 37 N., 8 W	5,500
Burns mine (S.)	Sec. 34. T. 36 N., 6 W	301
Clinton mine (S.)	Sec. 26, T. 36 N., 6 W	22,087
Hyer mine (K.)	Sec. 26, T. 36 N., 7 W	1,200
James mine (K.)	Sec. 29, T. 38 N., 6 W	30,000
Kelley mine No. 1 (K.)	Sec. 18, T. 36 N., 8 W	3,000
Kelley mine No. 2 (K)	Sec. 21, T. 37 N., 8 W	1,070
Lamb mine (S.)	Sec. 35, T. 36 N., 6 W	4,573
Lenox mine (J.)	Sec. 36, T. 37 N., 7 W	720
Meramec mine (J.)	Sec. 1, T. 37 N., 6 W	375,000
Moselle mine No. 9 (K.)	Sec. 29, T. 38 N., 6 W	14,000
Moselle mine No. 10 (K.)	Sec. 20, T. 36 N., 8 W	10,000
Organ mine (J.)		12
Reed mine (Wo.)		450
Smith mines Nos. 1, 2, 3 (S.)	Sec. 26, T. 36 N., 6 W	9,050
South Mountain mine (J.)	Sec. 23, T. 38 N., 6 W	800
Stimson	Sec. 10, T. 36 N., 6 W	5,844
Thornton-Dowling mine (K.)	Sec. 33, T. 38 N., 6 W	2,300
Taylor's Rolla mine (K.)	Sec. 15, T. 37 N., 8 W (?)	5,000
Winkler mine (S.)	Sec. 14 or 22, T. 36 N., 6 W	392
Other small mines (Wo.)		815
Estimated production of other mines including Thompson Railroad Nos. 1, 2 and 3, Piney Creek, Cold Spring, Santee and Clark's, Agricultural College No. 1, and Hancock mines		20,000
Total		562,772

[1] Productions for last eight months of 1891 and for all of 1892 are estimated.

ST. FRANCOIS COUNTY.

Name.	Locality.	Production. Gross Tons.
ron Mountain mine	Sec. 31, T. 35 N., 4 E.	3,516,969.

MISCELLANEOUS.

	Gross Tons.
Estimated production from a number of mines, chiefly of limonite ore in several counties from which no reliable information could be obtained, including Saline, Callaway, Washington, Wayne, Bollinger, Camden, Marion, Oregon and Butler, is	43,830

SUMMARY OF PRODUCTIONS OF COUNTIES BY CLASSES OF ORE.

SPECULAR ORES IN PORPHYRY.

County.	Production.
Iron	1,684,872
St. Francois	3,516,969
Total	5,201,841

SPECULAR ORES IN SANDSTONE.

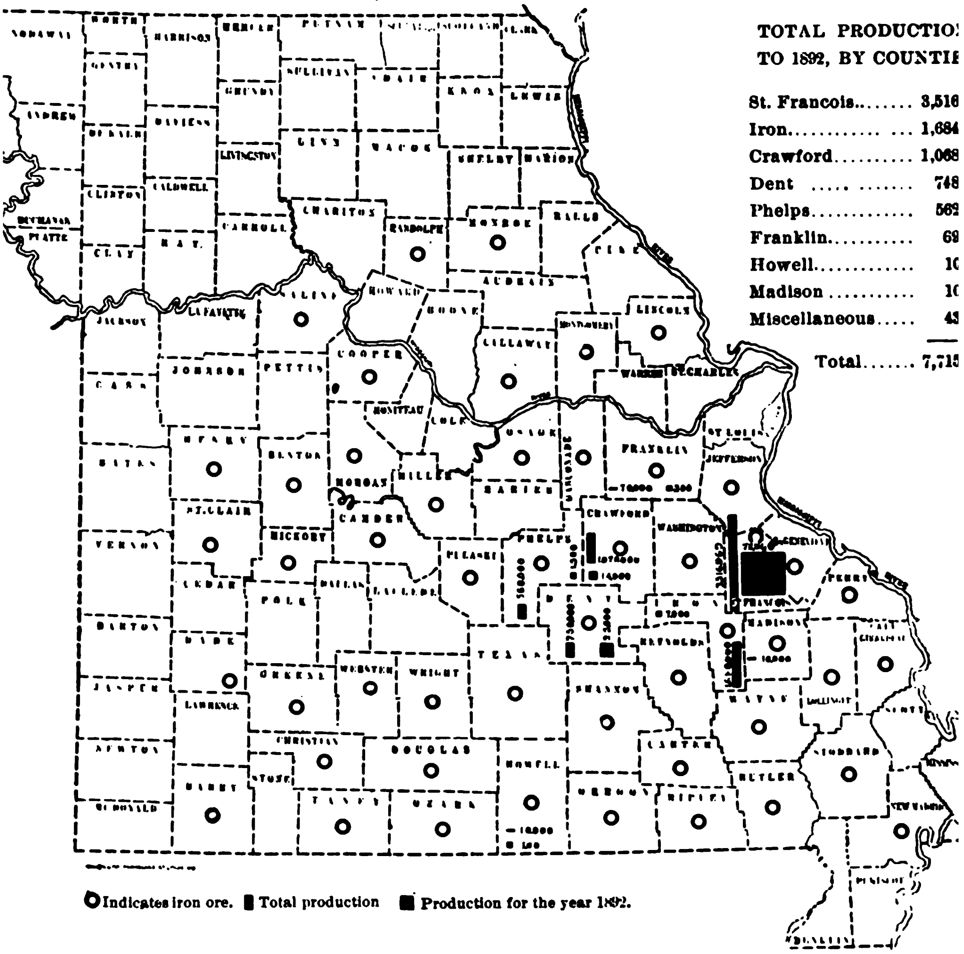
Crawford	1,068,154
Dent	748,827
Franklin	69,700
Phelps	562.772
Total	2,249,453

LIMONITE ORES.

Howell	10.000
Madison	10,000
Total	20,000
Miscellaneous	43,830
Grand Total	7,715,124

The preceding tables give, with reasonable completeness and detail, the geographic distribution of ore, and this is graphically shown in the small map opposite this page. There remains to be considered the chronologic distribution, or the production by

Last half of 1882 estimated.



TOTAL PRODUCTIO
TO 1892, BY COUNTIE

St. Francois........	3,516
Iron............ ...	1,684
Crawford..........	1,068
Dent	748
Phelps............	562
Franklin..........	69
Howell............	1(
Madison	1(
Miscellaneous.....	43
Total.......	7,715

FIG. 61. Outline map of the State of Missouri, showing counties containing iron ores and the distribution of productions to date.

years. Unfortunately, data for this purpose are exceedingly scarce and difficult to obtain. It was only after persistent inquiry and application that the total productions of the various mines given above were obtained, and, when attempt was made to obtain, further, the annual products and values of the same, the task soon proved itself hopeless of accomplishment, with the means and time available. Of many of the mines no such annual records were kept, and, of others, the books were destroyed or were buried in old ledgers, now practically inaccessible. We, therefore, have to content ourselves, for the present at least, with such details of annual productions as are given with the larger mines in the historical sketch and with the summaries contained in the next following table. The diagram on the next page illustrates graphically the same series of facts.

TABLE OF TOTAL ANNUAL PRODUCTIONS OF IRON ORES IN MISSOURI.

Years.	Production. Gross. Tons.	Estimated Average Value per ton.	Total Values	Authority for Tonnages.
Prior to 1850.......	100,000			Edwin Harrison.
1850-1860, incl......	310,000	$3 00	$3,105,000	" "
1861-1869, incl.. ...	625,000			" "
1870...........	316,000			" "
1871...........	240,000	5 00	15,693,470	" "
1872-1879, incl......	2,582,694			
1880..........	386,197	4 33	1,674,875	10th Census. Vol. XV., p. 48.
1881-1882, incl......	604,007	4 50	2,718,031	
1883........ ..	295,430	3 40	1,004,462	Min. Res. U. S., '83, p. 262.
1884...........	233,235	3 40	792,999	" " " " " "
1885..........	234,160	2 70	632,232	" " " '85, " 188.
1886...........	379,776	2 60	987,418	" " " '86, " 14.
1887...........	427,785	2 80	1,117,798	Swank, Ann. Stat. Rep. Am. Iron & Steel Ass. for 1889.
1888...........	217,931	2 60	566,620	Swank, Ann. Stat. Rep. Am. Iron & Steel Ass. for 1889.
1889....... ...	265,718*	2 20	584,580	Birkinbine, Am. Iron & Steel Ass. for 1891.
1890...........	232,835*†	2 20	512,237	Report of State Mine Inspector, C. C. Woodson, for 1890†
1891.	138,356*	2 50	345,890	Report of State Mine Inspector, C. C. Woodson, for 1891†
1892...........	126,000	2 50	315,000	Report of State Mine Inspector, C. C. Woodson, for 1892.†
Total...........	7,715,124		$30,050,612	

† Birkinbine's figures for 1890 are 181,690 tons.

* The figures given by Swank in the Ann. Stat. Rep., Am. Iron & Steel Ass., for 1889, are 233,784; 1890, are 182,693; 1891, 85,489.

† But apply to *shipments* of ore, and not to actual *production*.

† All of State Mine Inspector C. C. Woodson's figures are for years ending June 30th, excepting 1892, where the production for the latter half of the year is estimated.

Sources of Information. For the productions of iron ore in the State previous to and including the year 1870, we are indebted

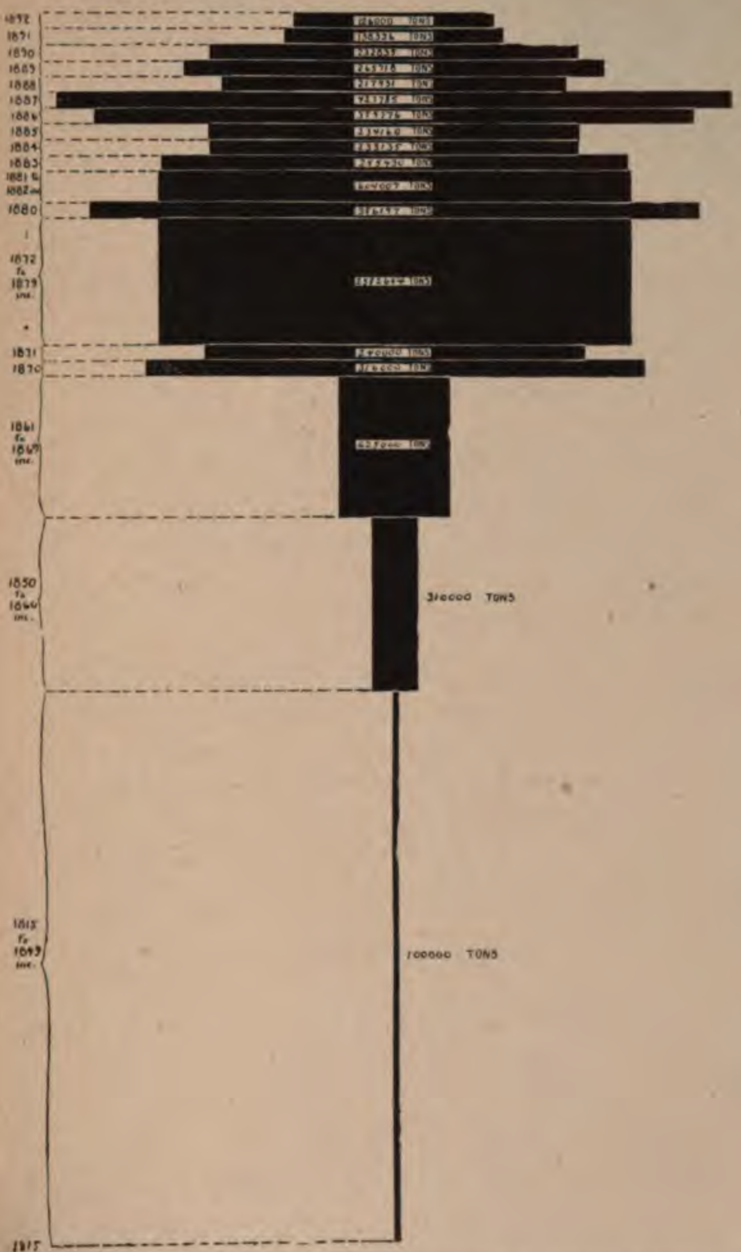


FIG. 62. Diagram illustrating growth of production of iron ore in Missouri, from 1815 to 1892.

Total production to date............7,715,124 tons.
Total value of product to date....... $30,050,612.

to results compiled by Mr. Edwin Harrison of St. Louis, and published in the *St. Louis Republican* of Jan. 1st, 1871. The production for the year 1871 is contained in the issue of the same paper of Jan. 1st, 1872. Concerning these figures, as well as those relating to the production of pig iron, Mr. Harrison writes as follows:

"Somewhere about 1870 to 1872, a representative of the *St. Louis Republican* requested me to give him a statement of the production of that metal (iron) up to date. At that time and for a number of years it was customary with the St. Louis journals to publish, on Jan. 1st, a review of the trade and manufactures of the city and, complying with the request, I gathered together all the data, and these were incorporated in that annual review. My recollection now is that my figures were all obtained directly from the various furnace operators and with assurances of their correctness, except in the case of the 'Old Springfield Furnace' which had ceased operations many years before and whose furnace stack was already growing picturesque as a ruin. From Col. McAllvaine, and such other old citizens as were best informed in relation to the operations of this furnace, however, I got all the information that was to be obtained regarding its capacity, number of years and months of actual running time and such other information as would lead to a fairly accurate estimate. No books which might have shown the production of this furnace had been preserved.

"I took much interest and great pains to obtain the most accurate statistics, as none had ever been collected on this point so far as I was either then or am now aware."

From 1872 to 1879, and 1881 and 1882 inclusive, we are entirely without figures of annual productions. Hence the amounts stated in the table are entirely estimated. As checks, we know that this was a period of great activity in iron mining in the State; we know the amounts produced at Iron Mountain during these years and at Cherry Valley during 1878 and 1879. Further, we know, from the preceding tables, the gross amount of iron ore produced in the State to date and, by difference, we deduce the amount which must be applied to these periods of darkness. The productions of the succeeding years have been

derived from various sources, as noted in the table. Regarding the figures for 1889, 1890 and 1891, according to different authorities, there is considerable discrepancy. We have introduced into the table those figures which we thought, from the manner in which they were collected, are most probably accurate. The statement in the foot-note shows clearly the differences between the results.

Estimates of Values. The values of the ores expressed in the table, can, at best, only be considered approximate estimates. Previous to the year 1870 we have not been able to obtain any data, but, as the production up to that period is not very large, an error in the assumed value will not affect the gross amount very much. During the years between 1870 and 1880, Iron mountain was a large producer and the ores were in great demand. Some large lots were then sold at $10.00 per ton and one lot at as high a figure as $15.00 per ton. These prices naturally bring the values of the period above the average; though, as we do not know the exact years or the amounts which commanded these prices the value is distributed over the probable period. For the year 1880 we quote the value given by the Tenth Census. From about 1880 to the present date we have the values for the porphyry ores cited on p. 309, and those for Cherry Valley cited on p. 314, as guides.

The production for the year 1892 is based upon the State Mine Inspector's, Mr. C. C. Woodson's, figures for the year ending June 30, 1892. It is, hence, in part, estimated. For purposes of exact reference his figures are given for each mine in the following table:—

PRODUCTION OF IRON ORE FOR THE YEAR 1892.

Name of Mine.	*Tons Mined.*	*Aver. Price Per Ton.*	*Total Value of Output.*
CRAWFORD COUNTY			
Cherry Valley mine	13,790	$2.43	$33,009.00
DENT COUNTY.			
Hawkins mine	10,100	1.75	17,675.00
Simmons Mountain mine	7,454	1.60	11,926.00
Craig and Plank mines	7,240	1.60	11,584.00
FRANKLIN COUNTY.			
Vicinity of Dry Branch	333	2.25	749.00

Name of Mine.	*Tons Mined.*	*Aver. Price Per Ton.*	*Total Value of Output.*
HOWELL COUNTY.			
Lamons mine	320	$2.00	$640.00
IRON COUNTY.			
Pilot Knob mine	7,049	2.07	14,591.00
PHELPS COUNTY			
Reed mine and others in vicinity of St. James	1,266	2.00	2,532.00
ST. FRANCIOS COUNTY.			
Iron Mountain mine	78,969	1.79	141,909.00
Totals	126,521	$1.85	$234,606.00

Missouri's Rank. Reviewing these tables and comparing the figures with those of other States in the Union, we learn that Missouri ranked sixth as an iron ore producer in 1880; in 1889 she ranked tenth; in 1891 thirteenth, and she now probably holds a still lower position. The rapid decline during the past few years is in large part due to the cessation of work at Pilot Knob.

THE METALLURGY OF IRON.

In the preceding notes on iron mining in the State frequent reference has been made to the establishment of furnaces at different points, more particularly to the early enterprises. In addition to what has there been said little can be added to the excellent Directory to the Iron and Steel Works of the United States, compiled and published for the American Iron and Steel Association by Mr. James M. Swank. The following extracts are therefore extracted, by permission, from several pages of that volume.

BLAST FURNACES.

Coke—In Operation.

Jupiter Iron Works, St. Louis County.—One stack, 75x20, finished in 1873, blown in for the first time in 1880, and remodeled in 1887. Fuel, coke: ores, Iron mountain, Pilot Knob, and about one-quarter red hematite.

Missouri Furnaces, St. Louis.—Two stacks, each 56x15, built

in 1870 and remodeled in 1887. Fuel, Connellsville coke; ores, Iron mountain and southwest; product, mainly Bessemer pig iron.

St. Louis Ore and Steel Company.— Two stacks at South St. Louis, St. Louis county, formerly called Vulcan Iron Works. One stack, 63x16, built in 1869, and one 75x18, built in 1872, and rebuilt in 1886. Fuel, Connellsville coke; ore, Pilot Knob; product, Bessemer pig iron.

Coke—Not Operated.

St. Louis Ore and Steel Company, St. Louis. One stack at South St. Louis, built in 1869; not likely to run again.

South St. Louis Furnaces, St. Louis. Two stacks, built in 1870 and 1872; dismantled.

Charcoal—In Operation.

Midland Furnace, at Midland, Crawford County.— One stack, 50x10, built in 1874–5, and blown in April 10, 1875; rebuilt in 1877. Ores, red and brown hematite; product, pig iron for steel purposes.

Pilot Knob Furnace, at Pilot Knob, Iron County.— One stack, 60x11 built in 1848; remodeled in 1879. Ore Pilot Knob; product, Bessemer pig iron.

Sligo Furnace, Dent county.—One stack, 55x11, built in 1880, and rebuilt in 1891. Ores, blue specular and red oxide, mined near the furnace; product, Bessemer, foundry and mill pig iron.

Charcoal — Not Operated.

Hamilton Furnace, Sullivan, Franklin County.— One stack, built in 1873:

Iron Mountain Furnaces, in St. Francois County.— Two stacks, built in 1846 and 1854; not in blast for several years.

Irondale Furnace, Irondale, Washington County.— One stack, built in 1859.

Knotwell Furnace, Newburg, Phelps County.— One stack, built in 1873-4.

Maramec Iron Works, in Phelps County.— One stack, built in 1826-9.

Moselle Furnace, Moselle, Franklin County.— Built in 1867.

Nova Scotia Furnace, Salem, Dent County.— One stack, built in 1880-1, machinery removed to Paducah, Ky., in 1888.

Osage Furnace, in Camden County.— Built in 1873.

Scotia Iron Furnace, Leasburg, Crawford County.— Built in 1870; abandoned in 1879.

ROLLING MILLS AND STEEL WORKS.

In Operation.

Granite Iron Rolling Mills, St. Louis.—Built in 1879. Product, stamping sheet iron for "granite iron ware" and galvanizing sheet.

Helmbacher Forge and Rolling Mills Company, St. Louis.—Built in 1858; product, bar, rod and band iron, coupling links and pins, car tender and locomotive axles, shafts and all kinds of forgings, for use of railroads, steamboats and machine shops.

Kansas City Bolt and Nut Company, Kansas City. — Works at Sheffield, Jackson county. Built in 1887–8, and first put in operation in January, 1889; product, bar and bolt iron; also bolts, nuts, spikes, etc.

St. Louis Ore and Steel Company.—Works at South St. Louis.—Built in 1872 as an iron-rail mill; Bessemer steel works, erected in 1875–6; made their first blow September 1, 1876; product, steel slabs, blooms, billets and rails.

St. Louis Steam Forge and Iron Works, St. Louis. — Built in 1862; product, bar iron, car axles, and railroad and steamboat forgings of iron or steel.

Union Steel and Iron Company, St. Joseph, Buchanan county. — Built in 1889; product, merchant iron and steel, sheet iron and steel, and steel nails. Works not yet put in operation.

Not in Operation.

Harrison Wire Company. — Built in 1873; machinery removed in 1887.

Laclede Rolling Mills, Chouteau, Harrison, and Valle Iron Company. -- Buil, in 1850 and rebuilt in 1879; product, bar, sheet, and plate iron and steel, blooms angles and tee iron, small T rails, spikes, nuts, bolts and washers; works dismantled in 1891.

La Grange Rolling Mills, La Grange, Lewis County. — Built in 1883; dismantled and machinery removed to Findlay, O., in 1887.

St. Louis Shovel Company, St. Louis. — One train of rolls used for rolling bars into shovel blanks; rolls removed and for sale.

Tudor Iron Works, St. Louis. Built in 1870; machinery removed to the Tudor Iron Works, East St. Louis, Ill., about 1881.

FORGES AND BLOOMARIES.[1] — (Abandoned.)

Germania Iron Works, Antony Zeitineger, South St. Louis, St. Louis County. — Built in 1871.

Kimmswick Forge, Kimmswick, Jefferson County. — Built in 1873; dismantled.

Maramec Iron Company, Maramec Iron Works, Phelps County.—Built in 1829.

BESSEMER STEEL WORKS.

(One completed and one partly built.)

St. Louis Ore and Steel Company. — Works at South St. Louis. Two 7-ton converters.

Union Steel and Iron Company, St. Joseph. — Two 3-ton Robert Bessemer converters partly built.

PLATE AND SHEET MILLS.

Granite Iron Rolling Mills, St. Louis Stamping Company. — St. Louis Iron and Steel sheets.

Union Steel and Iron Company, St. Joseph. — Iron and steel sheets. Not in operation.

CUT NAIL MILLS.

Union Steel and Iron Company, St. Joseph. — Fifty nail machines. Not in operation.

WIRE NAIL WORKS.

St. Louis Wire Mill Company, St. Louis. — Draws wire and makes all sizes of wire nails.

WIRE MILLS.

St. Louis Wire Mill Company, St. Louis.

[1] None are in operation at present.

CAST-IRON PIPE WORKS.

Shickle, Harrison, and Howard Iron Company, St. Louis.

South St. Louis Foundry, St. Louis. — Works at South St. Louis.

CAR-AXLE WORKS.

Helmbacher Forge and Rolling Mills Company, St. Louis.

St. Louis Steam Forge and Iron Works, St. Louis.

CAR-WHEEL WORKS.

Kansas City Car and Wheel Company, St. Louis. — Works at Birmingham.

Missouri Car and Foundry Company, St. Louis. — Product, cast iron wheels.

St. Charles Car Company, St. Charles. — Product, chilled charcoal cast iron wheels.

St. Louis Car-Wheel Company, St. Louis. — Product, cast iron wheels.

Treat, C. A., Manufacturing Company, Hannibal. — Product, cast iron wheels.

CAR BUILDERS.

Brownell Car Company, St. Louis. — Street cars only.

Kansas City Car and Wheel Company, St. Louis. — Works at Birmingham.

Laclede, The, Car Company, St. Louis. — Street cars only.

Missouri Car and Foundry Company, St. Louis.

St. Charles Car Company, St. Charles.

St. Louis Car Company, St. Louis. — Street, cable and electric cars and suburban coaches.

Whitman Agricultural Company, St. Louis. — Construction, dump, and clay cars.

TIN PLATE WORKS.

Granite Iron Rolling Mills, St. Louis.—Tinning plate added to rolling mill in 1890; first tin plates made in November, 1890, and first terne plates in March, 1891.

THE PRODUCTIONS OF IRON.

The productions of manufactured iron in the State are expressed in the following tables. The data for these are principally obtained from the Annual Statistical Tables of the American Iron and Steel Association, compiled by Mr. J. M. Swank. It is to be regretted that we are unable to introduce more detail as well as some figures relating to values of products.

PRODUCTIONS OF PLATE AND SHEET IRON AND ROLLED IRON.

YEAR.	Plate and Sheet Iron. Net Tons.	Rolled Iron. Net Tons.
1883	6,168	15,533
1884	6,892	18,580
1885	4,919	11,547
1886	6,791	15,800
1887	3,000	14,334
1888	3,390	12,867
1889	3,450	15,975
1890	.....	22,990

PRODUCTION OF PIG IRON IN MISSOURI.

UP TO THE END OF THE YEAR 1891.

YEAR.	PRODUCTION. Charcoal Iron. Net Tons.	Coke and Bituminous Coal Iron. Net Tons.	Bessemer Pig. Net Tons.	Total. Net Tons.	Price of No. 1 Anthracite Pig in Philadelphia. From annual statistical report of the American Iron & Steel Association for 1889.	AUTHORITY FOR TONNAGES.
Prior to 1850	....	......	......	40,000	....	Edwin Harrison.
1850-1860	.....	......	......	110,000	......	" "
1861-1869 incl	....	......	......	210,000	......	" "
1870	....	......	......	72,503	$33 25	" "
1871	35,656	38,170	......	73,826	35 12½	Mo Rep., Jan. 1st, 1872.
1872	......	......	......	101,158	48 87½	J. M. Swank, from Ann. Statistical Rep., Am. Iron & Steel Ass. for '9
1873	......	......	......	85,532	42 75	Ibid.
1874	......	......	......	75,817	30 25	"
1875	......	......	......	59,717	25 50	"
1876	......	......	......	68,223	22 25	"
1877	......	......	......	73,565	18 87½	"
1878	......	......	......	47,499	17 62½	"
1879	......	......	......	84,673	21 50	"
1880	......	......	......	105,555	28 50	"
1881	......	......	......	100,799	25 12½	"
1882	......	......	......	113,644	25 75	"
1883	......	......	......	103,206	22 37½	"
1884	31,558	28,485	......	60,043	19 87½	"
1885	21,785	29,623	......	51,408	18 00	"
1886	20,177	54,355	......	74,532	18 75	"
1887	40,752	97,891	122,725	138,643	21 00	"
1888	28,297	63,486	76,590	91,783	18 87½	"
1889	32,680	53,510	73,845	86,190	17 75	"
1890	33,965	66,585	69,454	100,550	......	"
1891	16,128	16,608	29,828	32,736	......	Ibid for 1891.
Totals	260,998	448,713	372,444	2,170,792		

GEOGRAPHICAL INDEX OF IRON ORE LOCALITIES IN MISSOURI.

All localities included in this list are described or referred to in this report, or are located on the accompanying map.

No.	Township.	Name of Mine or Owner.	Section.	County.	Page where describ'd
1	21 n., 10 w	Smith, Tyree & Howard	Sec. 7, s. w. ¼	Howell	246
2	22 n., 3 e.	Wilson, Robert, land	Sec. 18, n.w. ¼	Ripley	260
3	" "	Agricultural College land, No. 2.	Sec. 19, n. side	Ripley	254
4	" 2 e.	Government land, No. 3	Sec. 7.	Ripley	256
5	" "	Collins, A	Sec. 12, n. w. ¼	Ripley	254
6	" "	Booker, J. S	Sec. 12, s. w. ¼	Ripley	254
7	" "	Miss. county	Sec. 13, s. e. ¼, s. e. ¼	Ripley	257
8	" "	Current River land	Sec. 24, n. ½	Ripley	255
9	" "	King, E. M	Sec. 24, s. w. ¼	Ripley	256
10	" 1 e.	Dalton, L. C.	Sec. 9	Ripley	255
11	" "	Williams, J. T., land	Sec. 10	Ripley	259
12	" "	Stoops, P	Sec. 14	Ripley	259
13	" "	Government land, No. 2	Sec. 16	Ripley	255
14	" "	Ripley county	Sec. 16	Ripley	258
15	" "	Stephens, W. W	Sec. 19, w. ½	Ripley	259
16	" "	Herr, C B.	Sec. 24, n ½	Ripley	256
17	" 5 w.	Boyd, T. J.	Sec. 29, n.w. ¼, n.w. ¼	Oregon	248, 317
18	" "	Ragan, T. B.	Sec. 33, n.e. ¼, n.w. ¼	Oregon	249
19	" "	Murray land.	Sec. 33, n.e. ¼, s.w. ¼	Oregon	249
20	" 6 e.	Folsom, Alexander, land, No. 3	Secs. 10 and 11	Wayne	270
21	23 n., 3 e.	Mabrey, T. W., land, No. 1	Sec. 23, n. w. ¼	Ripley	257
22	" "	Gray, Mrs. Lydia	Sec. 31	Ripley	255
23	" "	Eaton, Z. A	Sec. 31	Ripley	255
24	" 2 e.	Government land, No. 4	Sec. 1	Ripley	256
25	" "	Mabrey, T. W., land, No. 2	Sec. 13.	Ripley	257
26	" "	Ponder, D. K	Sec. 26, s. e. ¼	Ripley	258
27	" "	Ponder, A. J	Sec. 26.	Ripley	258
28	" 1 w.	Ranken, Thos. J	Sec. 35.	Ripley	259
29	" 3 w.	Mt. Nebo.	Sec. 8	Oregon	249
30	" 11 w.	Wells land.	Sec. 5.	Ozark	258
31	" "	Mattney, J	Sec. 6.	Ozark.	251
32	" "	Owens, J	Sec. 6.	Ozark.	252
33	" "	More land	Sec. 35.	Ozark.	251
34	" 12 w.	Martin, Andrew.	Sec. 1.	Ozark.	251
35	" "	Mahan land.	Sec. 1, n. ½	Ozark.	251
36	" "	Cobb, H. C	Sec. 23, n. w. ¼.	Ozark.	250
37	" "	Lamb, John	Sec. 25	Ozark.	250
38	24 n. 6 e.	Allen bank.	Sec. 4, w. ½, n. w. ¼.	Butler	237
39	" 4 w.	Hains, J. N	Sec. 34	Oregon	173, 249
40	" 8 w.	Lamons mine	Sec. 35	Howell	165, 179, 190, 246, 317, 320, 321
41	" 11 w.	Pratt, Wallace.	Sec. 17	Ozark.	252
42	" "	S. Mo. Land Co., land, No. 1	Sec. 29	Ozark.	252
43	" "	Collins, T.	Sec. 30	Ozark.	250
44	" "	James, Wm.	Secs. 27 and 34	Ozark.	250
45	" "	S. Mo. Land Co., land, No. 2	Sec. 34	Ozark.	253
46	" 12 w.	Luna, Richard	Sec. 21.	Ozark.	250
47	" "	Tanner land	Sec. 34	Ozark.	253
48	" "	Warren, Judge P	Sec. 36.	Ozark.	253
49	" "	Mahan land.	Sec. 36, s. ½.	Ozark.	251
50	25 n., 6 e.	Swattler bank.	Sec. 28, n. e. ¼, n.w. ¼.	Butler	240
51	" 4 e.	Government land, No. 1	Sec. 24, s. e. ¼, s. e. ¼.	Butler	237
52	" "	Mo. L. & M. Co., land, No. 1	Sec. 36	Butler	239
53	" 3 e.	Mo. L. & M. Co., land, No. 4.	Sec. 19, n. ½	Ripley	257
54	" 2 e	Odom, Mrs., and Mo. L. & M. Co. land, No. 5	Sec. 31	Ripley	258
55	" 6 w.	Old, J. B.	Sec. 26	Oregon	167, 171, 249
[illegible]	[illegible] n., 8 e.	Goforth, Mrs. R. A	Sec. 2, n. w. ¼	Stoddard	263
[illegible]	" "	Hall, H. E	Sec. 3, w. ½	Stoddard	264

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59 ..	" "	Wommack & Chapman......	Sec. 4, n. e. ¼.........	Stoddard..	265
60 ..	" "	McGown, Joseph	Secs. 10 and 11.....	Stoddard..	264
61...	" 7 e..	Indian ford bank, No. 4.........	Sec. 22, s. ½, n. w. ¼	Butler	239
62 ..	" "	Indian ford bank, No. 2 .... / Indian ford bank, No. 3	Sec. 23, n. e. ¼...... / Sec. 23, n.e. ¼, s.w. ¼	Butler......	239
63 ...	" "	St. Francis bank.	Sec. 24, s. ½, n.w. ¼...	Butler.....	239
64 ..	" "	Indian ford bank, No. 1.	Sec. 24, n. ½, n. e. ¼.	Butler.. ..	238
65 ..	" "	Blue Spring bank.	Sec. 26, s. e. ¼, s. e. ¼.	Butler.....	237
66 .	" 6 e ..	Hendrickson mine	Sec. 18	Butler.....	178
67 ..	" "	Hendrickson, N. W.	Sec. 20.........	Butler . .	239
68 ..	" "	Agricultural College land, No. 1 .	Sec. 21	Butler. .	237
69 ..	" "	Indian creek bank...............	Sec. 35, n. w. ¼ . .	Butler.....	238
70 ..	" "	Miller bank	Sec. 35. n.w. ¼, n. e. ¼	Butler . .	239
71...	" 5 e..	Singer, Nimick & Co.............	Sec. 5	Wayne ..	276
72...	" 2 e...	Missouri L. & M. Co..............	Sec. 7, s.w. ¼, s.w. ¼ ..	Carter	242
73 ..	" "	Smith, David	Sec. 17, e. ½	Carter. .	242
74 ..	" 1 e..	Mo. L. & M. Co., land, No. 3......	Sec. 12, s. ½, s.w. ¼...	Carter...	242
75..	" "	Carter, A., and Mo. L. & M. Co. land, No. 2..................	Sec. 13, n.w. ¼..	Carter......	242
76...	" "	Kelly, Mrs. M....................	Sec. 13, s. e. ¼.... .	Carter ...	242
77 ..	" 1 w..	Brown, J. C., land, No. 2.........	Sec. 13, w. ½, s.w. ¼...	Carter	241
78 ...	" 5 w..	Phennighausen, R. W............	Sec. 11, n. e. ¼	Shannon. ..	263
79....	" "	Fisher, Joseph..................	Sec. 14, s. w. ¼........	Shannon....	262
80...	" "	Reaser, J. B	Sec. 14, s. w. ¼ . ..	Shannon.. .	262
81 ..	" 6 w...	Biser, C. T.	Sec. 10, n. ½, s.w. ¼...	Shannon. .	263
82 ..	" 11 w..	Tettrick, Henry.	Sec. 25.	Douglas..	244
83 ...	" 12 w..	Beazley, W. R., land..	Sec. 3, s.w. ¼, s.w. ¼..	Douglas ...	244
84....	27 n., 9 e...	Burger, Wm	Sec. 17	Stoddard ..	265
85...	" 8 e .	Moss, T. J	Sec. 6	Wayne.. ..	272
86 ...	" "	Hawks, F. T. and Houck, S......	Sec. 30..................	Stoddard..	264
87 ..	" "	Spiva bank	Sec. 26...............	Stoddard..	178
88...	" "	Smith land....................	Sec. 33, n. ½...... ...	Stoddard...	265
89 ..	" "	Thelenius, G. C..................	Sec. 34, e. ½..........	Stoddard ..	265
90 .	" "	Purcell, H. B	Sec. 36................	Stoddard..	264
91...	" 7 e...	Jones, A. S.	Sec. 3.................	Wayne.....	272
92...	" "	Neighbors, John.................	Sec. 6, n. e. ¼	Wayne.....	274
93 ...	" "	Smith, Pleasant................	Sec. 6, w. ½, lot 1, n.w ¼	Wayne.....	278
94 ..	" "	Moss and Clarkson land.	Sec. 16, n. ½	Wayne....	273
95 ..	" "	Mason and Clarkson land........	Sec. 16, e. ½	Wayne...	272
96	" "	Pettit bank	Sec. 19, s. e. ¼	Wayne.. .	277
97 ..	" 6 e	Folsom, Alexander, land, No. 1 / Folsom, Alexander, land, No. 2	Sec. 2	Wayne.. ..	[illegible]
98 .	" "	Deaton, Joseph D................	Sec. 7	Wayne...	278
99 ..	" "	Shrout's bank	Sec. 16, n.e. ¼, n.e. ¼..	Butler ..	240
100 ..	" 6 e .	Ozark Land Company...........	Sec. 17	Wayne.. .	274
101 ..	" "	Maxfield, J. C..	Sec. 18, n.e. ¼, n.e. ¼	Wayne..	272
102 ...	" "	Joiner, bank	Sec. 19	Wayne.. ..	271
103 ..	" "	Moss, T. J.	Sec. 19	Wayne.. .	274
104	" "	Mann bank	Sec. 21	Wayne.. .	272
105 ..	" "	Hanlan land ...,.	Sec. 21	Wayne.. .	278
106 ..	" "	Hicks, A. J	Sec. 23	Wayne.. ..	271
107 .	" "	Gary, A., and Moss, T. J	Sec. 24, s.w ¼	Wayne.. ..	[illegible]
108 ..	" "	Moss, T. J	Sec. 25, w. ½, n. e. ¼ ..	Wayne..	272
109 .	" "	Boucher, E. G	Sec. 25, n.w. ¼, s.e. ¼ ..	Wayne..	[illegible]
110	" "	Gary, A	Sec. 26, s.w. ¼, n.e. ¼. .	Wayne..	[illegible]
111 ..	" "	Burdinaux, Wm.	Sec. 36, n.e. ¼, n.e. ¼.	Wayne..	[illegible]
112 .	" "	Osgood, L. S	Sec. 36, n. ½, n.w. ¼..	Wayne..	[illegible]
113 .	" 5 e .	Otter creek bank	Secs. 3 and 4	Wayne..	274
114 ..	" "	Hayme Hollow bank..........	Sec. 5	Wayne...	[illegible]
115 .	" 5 w	Cutler, W. P	Sec. 33, n.e. ¼, s.w. ¼ .	Shannon.	261
116 ..	" 6 w	Government	Sec. 24, s.e. ¼, s.e. ¼..	Shannon .	263
117 ..	" 9 w	Godsey, D.	Sec. 26.	Howell . .	246
118 .	" 11 w..	McCrary, R. A., land	Sec. 14, w. ½, n.w. ¼..	Douglas..	244
119 ..	" 12 w..	Wood, D. S	Sec. 27, s.w. ¼	Douglas.. .	244
120	28 n., 8 e	Dondore, L. T	Secs. 7, 8, 17 and 18 ..	Bollinger.	234
121	" 7 e	Bennett, Perry.	Sec. 30	Wayne......	278
122	" 6 e	Reese creek bank	Sec. 5	Wayne.. .	275
123	" "	Holladay, H. N.	Sec. 5, s.w. ¼...... ..	Wayne......	[illegible]
124 ..	" "	Sneathen & Co . land, No, 1.	Sec. 8 s.w. ¼	Wayne.. .	276
125 .	" "	Berry, Wm., land, No. 1	Sec. 15	Wayne.. .	[illegible]
126	" "	Berry, Wm., land, No. 2	Sec. 15, s.w. ¼.... .	Wayne..	[illegible]
127 ..	" "	Johnson, Lewis, bank	[illegible].e. ¼, s.w. ¼	Wayne..	271
128 .	" "	Sneathen & Co., land, No. 1....	[illegible] and 23......	Wayne....	[illegible]
129	" "	Tower, Geo. F	[illegible].e. ¼.... ...	Wayne.. .	[illegible]

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130	25 n., 6 e	Atkins estate land	Sec. 19, n.w. ¼	Wayne	276
131	" "	Sneathen & Co., land, No. 2.	Sec. 22.	Wayne	276
132	" 3 e	Cedar Bay bank	Secs. 14 and 23	Wayne	162, 268
133	27 n., 5 e	Clarkson heirs	Sec. 5, s. ½	Wayne	278
134	" "	Haynie, S. C.	Sec. 7, s. w. ¼	Wayne	270
135	" "	Railroad bank	Sec. 8, s. e. ¼	Wayne	275
136	" "	Bossanbin, B	Sec. 9.	Wayne	277
		Bossanbin, B	Sec. 12.		278
137	" "	Moritz, G. F.	Sec. 12.	Wayne	273
138	" "	Holladay, H. N. and Haynie, S. C.	Sec. 20.	Wayne	271
139	" 4 e	Morris creek bank	Sec. 35, s. e. ¼	Wayne	273
140	" 3 e	Moreland bank	Sec. 28, n. e. ¼, n. e. ¼.	Carter	242
141	" 2 e	O'Reilly, Patrick	Sec. 2, e. ½	Carter	242
142	" 1 e	Shaw, David.	Sec. 6, w. ½, lot 1, s.e. ¼	Wayne	275
143	" "	Brown, J. C., land, No. 1.	Sec. 35, n. ½	Carter	241
144	" 3 w	Munsell, L. W.	Sec., n. e. ¼, s. e. ¼	Shannon	262
145	" 4 w	S. Mo. Land Company	Sec. 4, s. ½	Shannon	263
146	" "	Livesay land	Sec. 28, n.w. ¼, s.w. ¼	Shannon	263
147	" "	Ozark Lumber Company	Sec. 34, w. ½	Shannon	263
148	" 5 w	Thomas, Wm.	Sec. 15, s. w. ¼	Shannon	263
149	" "	Government.	Sec. 19, s.w. ¼, s.w. ¼	Shannon	263
150	" "	Knight, S. H.	Sec. 27, s.w. ¼, n.e. ¼	Shannon	263
151	" "	Butler, D	Sec. 28, n. ½	Shannon	263
152	28 n., 2 w	Abbott, M.	Sec. 31, s. e. ¼, s. e. ¼	Carter	242
153	" 3 w	Munsell, L. L.	Sec., s. w. ¼, n. e. ¼.	Shannon	263
154	" "	Deweese, J. N.	Sec. 6, s. w. ¼, n. e. ¼	Shannon	263
155	" "	Munsell, L. L.	Sec. 17, n. ½, n. e. ¼.	Shannon	263
156	" 3 w	Dean, J. H., land	Sec. 30, s. ½, lot 2, n.w. ¼	Shannon	261
157	" 4 w	Embree land	Sec. 12, n.w. ¼, n.w. ¼.	Shannon	261
158	" "	Government land, No. 5.	Secs. 24 and 25	Shannon	262
159	" 5 e.	Rubottom, L.	Sec. 10	Wayne	275
160	" "	Dalton, Mrs. N. T	Sec. 11	Wayne	269
161	" "	Bennett, Perry	Sec. 26.	Wayne	278
162	" "	Holladay, H. N.	Sec. 35	Wayne	278
163	" "	Mason and Clarkson	Sec. 35	Wayne	278
164	" 11 w	Smalley, H. H.	Sec. 36	Texas	266
165	29 n., 9 e.	Lemon, Thompson, land.	Sec. 3, s. ½, lot 3	Bollinger	234
166	" "	Revelle, J. W.	Sec. 10, n.e. ¼, s. w. ¼	Bollinger	235
167	" "	Bollinger, B. H	Sec. 31	Bollinger	233
168	" 7 e.	Speer's mountain	Sec. 3, w. ½, lot 2, n.w ¼	Wayne	277
169	" 4 e.	Clark's mountain.	Sec. 5	Wayne	42
170	" 3 e.	Bear mountain bank	Sec. 2, n.w. ¼	Wayne	178, 267
171	" 1 w	Blanton limonite bank	Sec. 29, s. ½ s. w. ¼.	Washingt'n	267
172	" 3 w	Tripp, G. W	Sec. 31, n. e. ¼, s. e. ¼	Shannon	262
173	" 4 w	Carson and James	Sec. 15, s. e. ¼	Shannon	263
174	" "	Chilton, W. S	Sec. 27, n. e. ¼, n.w. ¼.	Shannon	261
175	" 9 w	Government land, No. 6	Sec. 6, e. ½, lot 3, n.w. ¼.	Texas	266
176	30 n., 9 e.	Lute's, Jesse, bank.	Sec. 11, n. e. ¼, n. w. ¼	Bollinger	234
177	" "	Murdock.	Sec. 16.	Bollinger	236
178	" "	Glenn, Emma, bank	Sec. 16.	Bollinger	178
179	" 8 e	Myer's bank	Sec. 32, s. e. ¼, n. e. ¼	Bollinger	235
180	" 4 e	Kister bank	Sec. 35, n. e. ¼, n. w. ¼	Wayne	272
181	" "	Yancey mountain bank	Sec. 35, n. w. ¼, n. e. ¼	Wayne	277
182	" 9 w	Smith, N. W.	Sec. 4, s. e. ¼, s. w. ¼	Texas	267
183	" "	Field bank	Sec 11	Texas	266
184	" "	Sutton, T. J.	Sec. 14, s. ½, n. e. ¼	Texas	267
185	" 10 w	Duke, M. E	Sec. 1.	Texas	266
186	" 25 w	Compton, G. A	Sec. 35.	Dade.	184
187	31 n., 10 e	Tibb's bank	Sec. 29, s. w. ¼	Bollinger	236
188	" "	Turkey hill bank.	Sec. 32, n. w. ¼	Bollinger	236
189	" 9 e	Robbin's bank	Sec. 10	Bollinger	236
190	" 8 e.	Gilman bank	Sec. 1, n. w. ¼	Bollinger	234
191	" "	Deal bank	Sec. 2	Bollinger	233
192	" "	Nifong bank.	Sec. 2, s. e. ¼	Bollinger	235
193	" "	Rhodes bank	Sec. 14, s. w. ¼	Bollinger	236
194	" 3 w	Biser, C. T.	Sec. 8, n. e. ¼	Shannon	263
		Biser, C. T.	Sec. 9, n. w. ¼		
195	" "	Woodside, L. B.	Sec. 15, s. ½.	Shannon	263
196	" 4 w	Midland Blast Furnace Co.	Sec. 21, n. w. ¼.	Shannon	263
197	" 5 w	Organ and Sweiney	Sec. 22, n. ½	Shannon	263
		Organ and Sweiney.	Sec. 34, s. ½.		
198	" 6 w	Mo. Furnace Company	Sec. 13, s. e. ¼, n. w. ¼	Shannon	263
199	" "	Seay, Gov. A. J	Sec. 16	Shannon	263
200	" 9 w	Roger's mill land	Sec. 23, n. w. ¼, n. e. ¼	Texas	230
201	32 n., 8 e	Poblick's bank	Secs. 23 and 24	Bollinger	234

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202	32 n., 6 e.	Matthews mountain	Sec. 3	Madison	249
203	" 2 w.	Lesterville bank	Sec. 8, n.e. ¼	Reynolds	254
204	" "	January mine	Sec. 20, n. e. ¼, n. e. ¼	Reynolds	230
205	33 n., 7 e.	Ford bank		Madison	246
206	" 7 e.	Foster bank	Sec. 16, n. e. ¼	Madison	247
207	" 4 e.	Shut-In mine	Sec. 3	Iron	307, 320
208	" 4 e.	Lewis mountain	Sec. 6, s. ½	Iron	47
209	" 3 e.	Russell mountain	Sec. 13	Iron	320
210	" 5 w.	Riverside-Ziegler mine	Sec. 2	Dent	32
211	33 n., 6 w.	Jamison mine	Sec. 1, s. w. ¼	Dent	222, 319
212	34 n., 4 e.	Cedar Hill	Sec. 19, s. w. ¼	Iron	16, 21, 34, 40, 47, 307, 320, 321
213	" "	Pilot Knob	Sec. 29, w. ½	Iron	17, 19, 21, 22, 32, 44, 48, 61, 84, 307, 320
214	" "	Shepherd mountain	Sec. 31	Iron	21, 22, 38, 41, 46, 49, 307, 320
215	" 1 w.	Burt mine	Sec. 2	Iron	224
216	" "	Rogers mine	Sec. 2	Iron	225
217	" 2 w.	Red Point land	Secs. 14 and 15	Iron	225
218	" 3 w.	Howe Mill mine	Sec. 9	Dent	222, 319
219	" 4 w.	Hutchins creek mine	Sec. 15	Dent	222, 319
220	" "	Fitzwater mine	Secs. 33 and 34	Dent	221, 319
221	" 5 w.	Norris mine	Sec. 12	Dent	319
222	" "	Hayes mine	Sec. 20	Dent	319
223	" 6 w.	Pomeroy mine	Sec. 10	Dent	223
224	" "	Ferguson mine	Sec. 13	Dent	319
225	" "	Orchard mine	Sec. 13, e. ½, s. e. ¼	Dent	154, 222, 319
226	" "	Thomas mine	Sec. 17	Dent	320
227	" "	Simmons mountain	Sec. 24, w. ½	Dent	119, 123, 136, 154, 212, 320, 327
228	" "	Orchard and Young, Thorpe, Preston or Pittsburgh mine	Sec. 27	Dent	319
229	" 7 w.	Clark-Taylor mine	Sec. 12	Dent	319
230	" "	Taylor mine	Sec. 12, s.w. ¼, s.w. ¼	Dent	223
231	" "	Causey bank	Sec. 35	Dent	149, 319
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233	" 3 e.	Buford mountain	Sec. 24	Iron	49, 307, 320
234	" 4 w.	Sligo mine	Sec. 2	Dent	154, 223
235	" "	Grover mine	Secs. 2 and 11	Dent	219
236	" 5 w.	Arnold mine	Sec. 4, s. e. ¼	Dent	220
237	" 6 w.	Blair mine	Sec. 9, s. ½	Dent	221
238	" "	Hawkins mine	Sec. 11	Dent	120, 154, 221, 314, 319, 327
239	" "	Graff, Blackwell mine	Sec. 12	Dent	319
240	" "	Williams mine	Sec. 16, n. ½	Dent	224
241	" "	Plank mine	Sec. 33	Dent	120, 221, 223, 319, 327
242	36 n., 4 w.	Thompson mine	Sec. [illegible]	Crawford	[illegible]
243	" "	Wilkerson bank	Sec. 34	Crawford	[illegible]
244	" 5 w.	James mine	Sec. 12	Crawford	[illegible]
245	" "	Bonito mine	Sec. 12	Crawford	[illegible]
246	" "	Pease mine	Sec. 13	Crawford	[illegible]
247	" "	Craig mine	Sec. 24	Crawford	[illegible]
248	" "	Benton creek mine	Sec. [illegible]	Crawford	[illegible]
249	" 6 w.	Stimson mine	Sec. 10	Phelps	[illegible]
250	" "	Winkler mine	Sec. [illegible]		
251	" "	African mine			
252	" "	Clark mine			
253	" "	Smith mines			
254	" "	Clinton mine			
255	" "	Lamb mine			
256	" "	Burns mine			

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258	" 8 w.	Moselle mine, No. 10	Sec. 20	Phelps	321
259	" "	Kelly mine, No. 1	Sec. 18, e. ½	Phelps	227, 321
260	37 n., 3 w.	Cherry Valley mines	Sec. 4	Crawford	118, 120, 122, 129, 136, 318, 132, 326
261	" "	Beaver creek mine	Sec. 33, s. ½	Phelps	226
262	" 4 w.	Seay mine	Sec. 5	Crawford	319
263	" "	Steelville mine, No. 1	Sec. 5, e. ½, s. w. ¼	Crawford	220, 312, 319
264	" "	Steelville mine, No. 2	Sec. 5, e. ½, s. w. ¼	Crawford	243, 312, 319
265	" "	Ferguson mine	Sec. 21	Crawford	218, 318
266	" "	Buffum mine	Sec. 32.	Crawford	318
267	" 5 w.	Hart mine	Sec. 24.	Crawford	418
268	" 6 w.	Meramec mine	Sec. 1, n. w. ¼	Phelps	120, 310, 321
269	" "	Williford mine	Sec. 36	Phelps	229
270	" 7 w.	Lenox mine	Sec. 36	Phelps	321
271	" 8 w.	Taylor's Rolla mine	Sec. 15, s. w. ¼	Phelps	229
272	" "	Beaver creek mine	Sec. 33	Phelps	321
273	38 n., 6 w.	South mountain mine	Sec. 23	Phelps	321
274	" "	James mine	Sec. 29	Phelps	321
275	" "	Moselle mine, No. 9	Sec. 29	Phelps	321
276	" "	Thornton-Dowling mine	Sec. 33.	Phelps	321
277	37 n., 8 w.	Kelly mine, No. 9.	Sec. 21, n. e. ¼	Phelps	227, 321
278	" "	Buckland mine	Sec. 2, s. ½	Phelps	226, 321
279	38 n., 3 w.	Scotia mine, No. 1	Sec. 1, e. ½, s. e. ¼	Crawford	220, 311, 318
280	" 6 w.	James and Moselle mine, No. 9	Sec. 29, s. ½, s. e.	Phelps	227
281	" "	Santee and Clark's mine	Sec. 33, s. w. ¼	Phelps	228
282	" "	Thornton mine	Sec. 33, n. e. ¼	Phelps	229
283	" 24 w.	Sheldon bank	Sec. 8.	St. Clair	260
284	39 n., 24 w.	Copper bank	Sec. 27	St. Clair	260
285	" 2 w.	Scotia mine, No. 2	Sec. 28, s. e. ¼	Crawford	220, 311, 319
286	" 5 w.	Iron Ridge mine, No. 1	Sec. 29, n. e. ¼	Crawford	219, 318
287	" "	Iron Ridge mine, No. 2.	Sec. 33	Crawford	219
288	" 18 w.	Furnace bank	Sec. 4	Camden	240
289	" "	White bank	Sec. 7, s. e. ¼	Camden	241
290	" 22 w.	Richwoods bank	Secs. 3 and 4	Benton	233
291	" 24 w.	Groves bank	Sec. 16	St. Clair.	281
292	" 25 w.	Greenwell bank	Sec. 15	St. Clair.	260
293	" "	Marmaduke bank	Sec. 23	St. Clair.	281
294	" "	Collins bank	Sec. 23	St. Clair.	281
295	40 n., 1 w.	Blanton specular mine	Sec. 29, n. e. ¼, s. e. ¼	Washington	231
296	" "	Primrose hill mine	Sec. 32, s. w. ¼, n. w. ¼	Washington	231
297	" 2 w.	Old Copper hill mine	Sec. 23, e. ½, n. e. ¼	Crawford	219
298	" 10 w.	Dunn, Raph, bank	Sec. 32	Callaway	279
299	" 19 w.	Wigwam bank	Sec. 10.	Morgan	248
300	" "	Palm bank	Sec. 12, n. w. ¼	Morgan	248
301	" "	Cout's bank	Sec. 14	Morgan	248
302	" 20 w.	Gun bank	Sec. 33	Benton	232
303	" 21 w.	Carpenter bank	Sec. 12.	Benton	232
304	" "	Grissom bank	Sec. 28.	Benton	232
305	41 n., 2 e.	Bowlen bank	Sec. 5, n. w. ¼	Franklin	245
306	" 1 w.	Anaconda	Sec. 16	Franklin	118
307	" "	Iron hill mine	Sec. 17.	Franklin	320
308	" "	Thurmond mine	Sec. 19, n. ½, n. w. ¼	Franklin	224
309	" 1 w.	Stanton hill bank	Sec. 36, s. w. ½, n. e. ¼	Franklin	156, 245
310	" 20 w.	Walker bank	Sec. 36	Benton	233
311	" 22 w.	Elm Hollow bank	Sec. 36.	Benton	232
312	" 25 w.	Brownington deposit	Sec. 20.	Henry	183
313	" 26 w.	Clinton deposit	In Clinton	Henry	183
314	42 n., 1 e.	Iron hill	Sec. 17	Franklin	245
315	" "	Wildy's (Isaac) mine	Sec. 17, s. w. ¼, s. w. ¼	Franklin	246
316	" 12 w.	Gaty, (E. W.) land	Sec. 21	Cole	243
317	" "	Lothian (B.) land	Sec. 22	Cole	243
318	" 21 w.	Indian creek bank	Sec. 26	Benton	233
319	43 n., 25 w.	Brown bank	Sec. 25.	Henry	280
320	45 n., 10 w.	Shaft hill	Sec. 4, n. w. ¼	Callaway	280
321	" "	Murphy's hill	Sec. 15	Callaway	280
[illegible]	" "	Old Diggings	Sec. 22	Callaway	280
	46 n., 10 w.	Knight bank	Sec. 2	Callaway	279
	" "	Dunn, Richard, bank	Sec. 21	Callaway	279
	" "	Dunn, Raph, bank	Sec. 32	Callaway	75, 279
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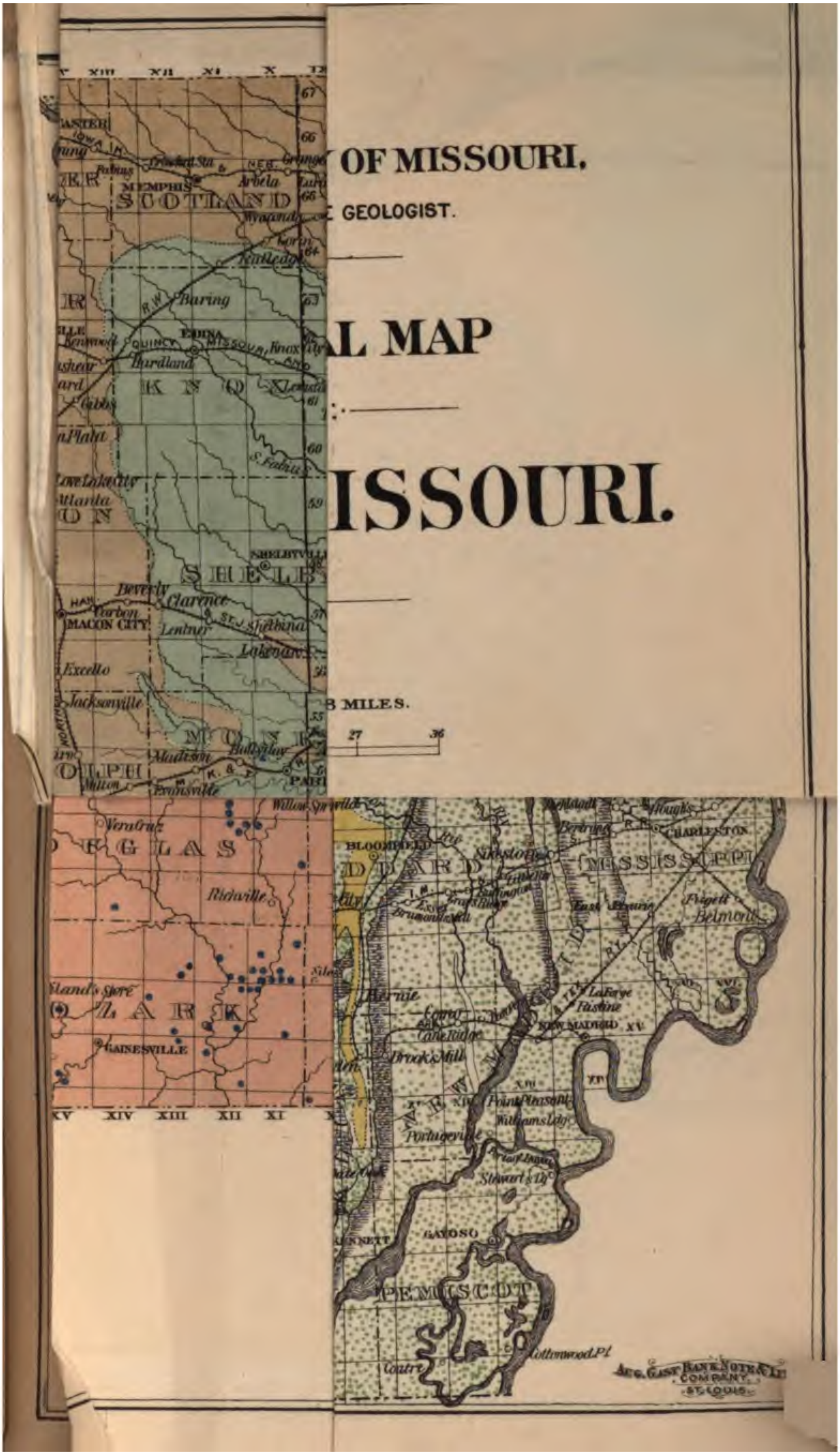
On page	xiv, eighth line from	top,	for	L. W.	read	L. L.
" "	4, fourth " "	bottom,	"	more	"	less.
" "	69, third " "	top,	"	Silurian	"	Cambrian.
" "	91, first foot-note,	.	"	6	"	90.
" "	96, eleventh line from	top,	"	these	"	three.
" "	100, second " "	"	"	40	"	96.
" "	107, fifteenth " "	"	"	29	"	28.
" "	110, sixteenth " "	"	"	of	"	on.
" "	113, fourt'nth " "	bottom,	"	Plate I	"	Plate III.
" "	139, in illustration read — Width of vein 8 feet.					
" "	146, sixth line from	top,	for	past	read	post.
" "	155, first " "	"	"	Kalbe	read	Kolbe.
" "	155, thirteenth " "	bottom,	"	Nos. 9 & 10	read	Nos. 11 & 12.
" "	155, first " "	"	"	No. 11	read	No. 13.
" "	156, first " "	top,	"	Nos. 12 & 13	read	Nos. 14 & 15.
" "	163, fifth " "	bottom,	"	grades	read	geodes.
" "	191, in foot-note		"	171	"	167.
" "	250, second title,		"	Lowell	"	Towell.
" "	257, thirteenth line from	bottom,	"	acres	"	areas.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PUBLICATIONS OF THE

GEOLOGICAL SURVEY OF MISSOURI.

SURVEY OF 1853 TO 1862.

G. C. SWALLOW, STATE GEOLOGIST.

The First and Second Annual Reports of the Geological Survey of Missouri, by G. C. Swallow, State Geologist, Jefferson City. 1855. Parts I and II, 208 and 240 pp., 69 illustrations and 5 small county maps. **Edition exhausted**

CONTENTS. First Annual Report — Administrative — pp. 19-22. Second Annual Report: Introduction, pp. 25 to 58. Part I, Chapter I: Geology of Missouri, pp. 59 to 136, by G. C. Swallow. Chapter II: Economical Geology, Soils, pp. 137 to 170. Chapter III: Special Report on Marion county, pp. 171 to 185. Chapter IV: Special Report on Cooper county, pp. 186 to 204. Chapter V: Geology of the Southwest, pp. 204 to 207. All preceding by G. C. Swallow.

Part II: Report on Lead Mines and Mining of Southeast Missouri, in the counties of Franklin, Jefferson, Washington, St. Francois and Madison, pp. 1 to 94, by A. Litton. Special report on Moniteau county, pp. 95 to 119, by F. B Meek. Description of the formations along the Hannibal & St. Joseph Railroad, with a catalogue of fossils collected, pp. 121 to 136, by F. Hawn. Geological Section on the Mississippi river, pp. 139 to 157; Special report on Franklin county, with map, pp. 157 to 169; Special report on St. Louis county, with map, pp. 169 to 184; Paleontology, including a description of 48 new species of fossils, with three plates of same, pp. 185 to 208, all by B. F. Shumard. Appendix, 31 pp., containing a list of publications previously made relating to the Geology of Missouri; a paper on the use of fossils, a catalogue of the fossils of Missouri and of her trees and shrubs, and a glossary of geological and other scientific terms.

The Third Report of Progress was transmitted in December, 1856, and is of 4 pages. It recites briefly what work has been done during the years 1855 and 1856. **Edition exhausted**

The Fourth Report of Progress was made in December, 1858, and is of 14 pages. This describes, in greater detail, the operations of the Survey during the years 1857 and 1858, and gives, in tabular form, a statement of progress to date. **Edition exhausted**

The Fifth Report of Progress of December 30, 1860, is of 13 pages and is a similar statement of operations during the years 1859 and 1860, with a brief reference to the results reached concerning the coal, lead and iron deposits and the soils of the State. In this report the product of the Survey to that time is given in tabular form. **Edition exhausted**

SURVEY OF 1870 TO 1874.

A. D. HAGAR, RAPHAEL PUMPELLY AND G. C. BROADHEAD, STATE GEOLOGISTS.

Annual Report of the State Geologist of the State of Missouri (Albert D. Hagar, Nov. 30, 1870), 23 pp., no illustrations. The progress of the Survey is described and the principal minerals and building stones are briefly noticed. **Edition exhausted**

Edition exhausted.

Report of the Geological Survey of the State of Missouri, 1855–1871. By G. C. Broadhead, F. B. Meek and B. F. Shumard, Jefferson City. 1873. pp. 323 and iv. 29 illustrations, 9 small county maps.

CONTENTS: It contains chapters on Maries, Osage, Warren, Shelby, Macon and Randolph counties by G. C. Broadhead; on Miller, Morgan and Saline counties by F. B. Meek; on Ozark, Douglas, Wright, Laclede, Pulaski, Phelps, Crawford, Cape Girardeau, Perry, Ste. Genevieve, Jefferson any Clark counties by B. F. Shumard.

Edition exhausted.

Preliminary Report on the Iron Ores and Coal Fields from the field work of 1872, with 190 illustrations in the text, and an Atlas. 1873. pp. xvi, 214 and 441. Atlas accompanying, 22x28 inches, with 14 large sheets. Jefferson City. 1874.

CONTENTS: Part I, Chapter I.—Notes on the Geology of Pilot Knob and its vicinity, by R. Pumpelly, pp. 3 to 28. Chapter II: Analysis of Ores, Fuels and Pig Irons, pp. 29 to 44. Chapters III, IV, V and VI, constitute a partial report on the Iron Ores of Missouri, by Dr. Schmidt, pp. 45 to 214.

Part II, Chapters I, II, III, IV, V and VI, contain general matter relating to the Coal Fields, by G. C. Broadhead, pp. 1 to 213. Chapters VII and VIII are on the geology of Lincoln county, by Wm. B. Potter, pp. 215 to 289. Chapters IX to XV, are reports by G. C. Broadhead on Livingston, Clay, Platte, Buchanan, Holt, Atchison and Nodaway counties, pp. 290 to 402. Appendices, A, B and C contain, respectively, the results of some tests of strength of building materials, a note relating to Missouri rocks which admit of a fine polish, and a list of Coal Measure fossils, pp. 403 to 420.

Edition exhausted.

Report of the Geological Survey of the State of Missouri, including field work of 1873–1874, with 91 illustrations and one Atlas, 13x15 inches, containing 15 sheets. Garland C. Broadhead, State Geologist, Jefferson City, Mo. 1874. pp. 734; L. 4, 56.

CONTENTS: Chapters I and II contain an historical introduction and a brief description of the General Geology of the State, pp. 5 to 34. Chapters III, IV and V treat, in a general way, of Caves and Water Supply, and of Soils and Timber, and the last Chapter contains a brief list of the Minerals of the State, pp. 35 to 56. Chapter VI contains remarks on the Southwest Coal Field, and is accompanied by a general section, pp. 56 to 61. Chapters VII to XXI, inclusive, are reports on Cedar, Jasper, Barton, Vernon, Bates, Howard, Sullivan, Adair, Linn, Putnam, Schuyler, Andrew, Daviess, Cole and Madison counties, pp. 62 to 379, all the preceding by G. C. Broadhead. Chapters XXII to XXVIII constitute a report on the Lead Region of Southwest Missouri, in which the general characteristics of the region and its ores are given, together with a description of a number of its deposits, pp. 381 to 502, by Dr. A. Schmidt. Chapters XXIX to XXXII treat similarly of the Lead Deposits of Central Missouri, pp. 503 to 577, also by Dr. Schmidt. Chapter XXXIII contains rules for the development of Iron Ore Deposits and Notes on the Metallurgical Properties of Missouri Iron Ores, pp. 578 to 600, by A. Schmidt. Chapter XXXIV is on the Lead Region of Southeast Missouri, pp. 601 to 637, by J. R. Gage. Chapter XXXV is on the Iron Ore of the same region, pp. 638 to 671, by P. N. Moore. Appendices A, B, C and D are brief papers on the "History of Lead Mining in Missouri," on "Lead Mines in Upper Louisiana," on "Metallic Statistics," and on "Mineral Springs of Missouri." Appendix E contains results of analyses of ores, fuels and minerals, pp. 672 to 734.

SURVEY OF 1876 TO 1879.

CHAS. P. WILLIAMS, ACTING STATE GEOLOGIST.

Edition exhausted.

Industrial Report on Lead, Zinc and Iron, together with notes on Shannon county and its copper deposits, by Chas. P. Williams, Ph. D., Acting State Geologist, Jefferson City. 1877. pp. 183 and xvi, 11 illustrations.

SURVEY OF 1889 TO DATE.

ARTHUR WINSLOW, STATE GEOLOGIST.

SUBJECT REPORTS.

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Vol. I.—**A Preliminary Report on the Coal Deposits** of Missouri from field work prosecuted during the years 1890 and 1891. With 131 illustrations,

by Arthur Winslow, State Geologist. Published by the Geological Survey. Jefferson City. Nov. 1891. 8vo., cloth, 227 pp.

CONTENTS: Chapter I: The Coal Measures, their distribution, topography, lithology and stratigraphy; the process of deposition, pp. 18 to 32. Chapter II: The Coal Beds, their distribution and character; the conditions restricting distribution and availability, pp. 33 to 41. Chapter IV: The Coal Industry, the coal production and market; the uses and adaptabilities of the coals; the available coal tonnage and the value of coal and coal lands, pp. 42 to 51. Chapter V: A systematic description, by counties, of coal beds now operated, including 57 counties, pp. 52 to 172. Appendix A: Notes on Coal Mining in thin coal beds, pp. 173 to 186. Appendix B: List of the Coal Operators of Missouri, pp. 187 to 199.

AREA OF SHEET REPORTS.

No. 1.—**A Report on the Higginsville Sheet,** Lafayette county, accompanied by a Geologic and Topographic Map and a Sheet of Sections. From field work prosecuted during the years 1890 and 1891. By Arthur Winslow, State Geologist. Published by the Geological Survey. Jefferson City. April, 1892. Folio, 22 pp. **Postage 12 cts.**

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BULLETIN No. 2.

CONTENTS: A Bibliography of the Geology of Missouri, by F. A. Sampson, 8vo. Paper. 158 and xviii pp. 819 titles. Table of Contents, author and subject indexes. Jefferson City. December, 1890. **Postage 6 cts.**

BULLETIN No. 3.

CONTENTS: The Clay, Stone, Lime and Sand Industries of St. Louis City and county, by G. E. Ladd, Assistant Geologist. 80 pp. The Mineral Waters of Henry, St. Clair, Johnson and Benton counties, by A. E. Woodward, Assistant Geologist. 8vo. Paper. 101 pp. 4 cuts. 2 maps. Jefferson City. December, 1890. **Postage 5 cts.**

BULLETIN No. 4.

CONTENTS: A Description of the Lower Carboniferous Crinoids from Missouri, by S. A. Miller. 8vo. Paper. 40 pp. 5 plates. Jefferson City. February, 1891. **Postage 4 cts.**

BULLETIN No. 5.

CONTENTS: The Age and Origin of the Crystalline Rocks of Missouri, by Erasmus Haworth. 42 pp. Notes on the Clays and Building Stones of Certain Western Central Counties Tributary to Kansas City, by G. E. Ladd, Assistant Geologist. Jefferson City. July, 1891. 86 pp. Paper. **Postage 5 cts.**

BIENNIAL REPORTS—ADMINISTRATIVE.

Biennial Report of the State Geologist, transmitted by the Bureau of Geology and Mines to the Thirty-sixth General Assembly. Small 8vo. Paper. 53 pp. 2 small diagrams. Consists of [illegible] of the progress of geological work in the State, and [illegible] ss. Jefferson City. December, 1890. **Edition exhausted.**